AMERICAN UNIVERSITY OF BEIRUT

RECEPTION AND USE OF ENERGY METAPHORS IN BIOLOGY BY ENGLISH LANGUAGE LEARNERS IN A LEBANESE INTERMEDIATE CLASSROOM

by
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ABSTRACT
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Many science concepts have a complex and abstract nature. One such concept is the concept of energy. The concept has somewhat different meanings in different scientific contexts (Lancor, 2014a) and students encounter the term energy in everyday contexts as well. All this affects students' conceptualization of the term energy (Amin, 2009a). Many studies have investigated teaching and learning about energy through the lens of conceptual metaphor theory and have reported that energy is construed metaphorically in various ways in scientific and everyday discourse. The present study aimed at examining the use and reception of energy metaphors by English language learners (ELLs) in a Lebanese school. The focus of this study was on energy metaphors used in textbooks and metaphors written by 7^{th} grade ELLs in the context of biology, specifically on energy in ecosystems. The use of metaphors can be misleading especially when taught to ELLs. The data sources analyzed in the study were the textbooks of grades four, five and seven, students' writings, and interview transcripts. The present study applied qualitative content analysis to examine the use of energy metaphors from a conceptual metaphors perspective in textbooks of lower grades and seventh grade textbook. Seventh grade students' writings, about the role of energy in an ecosystem were also analyzed and compared to the usage of metaphors in the textbooks students were exposed to. Interviews were conducted to explore students' understanding and awareness of the energy metaphors they used in their writings. Metaphorical construal of the Object Event Structure metaphor and the Location Event Structure metaphor reflecting energy transfer, transformation, conservation, and degradation were identified in the textbooks. Notable similarities were found between the metaphors used by the students and the metaphors found in textbooks. The categories and conceptual metaphors identified in the textbooks were sufficient to categorize the expressions written by the students. Energy transfer was reflected the most in the metaphors used by the students and fewer metaphors dealing with energy transformation were evident. Energy conservation and energy degradation were hardly addressed by the metaphors written by the students. The interviews revealed some misconceptions students have about energy transformation and in many cases students were not able to elaborate on expressions addressing energy transformation or degradation. When exploring the students' metalinguistic awareness of metaphors, students showed understanding of the metaphorical nature of English expressions. Students did not, however, show any awareness of the metaphorical nature of the energy expressions they used. The findings of the study suggest targeting students' awareness of the metaphorical nature of energy expressions taught to design class activities that enhance the acquisition of a

comprehensive understanding of energy. Revisiting the curriculum was also considered, focusing on using energy construals, easily picked up by students, to describe energy transfer. Those construals could be used to teach about energy transformation and degradation in parallel to energy transfer.

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CHAPTER 1

INTRODUCTION

Background and Rationale

Children come to class already possessing a well-developed body of knowledge that enables them to explain certain phenomena from their everyday life experiences, even if this knowledge is not consistent with the formal scientific theories they are taught. Those conceptions, however, are often difficult to extinguish or change through teaching (Amin & Levrini, 2018; Carey, 1986; McCloskey and Kargon, 1983; Smith, Roschelle and diSessa, 1993; Vosniadou and Brewer, 1992; Vosniadou, 2013). Supporting conceptual change becomes the duty of the teacher. It all starts with the initial conceptions. When we talk about conceptual knowledge, we are not talking about single independent elements but of knowledge systems composed of many interrelated elements that can change in complex ways (Smith, Roschelle and diSessa, 1993). According to Treagust and Duit's (2008) description of constructivist epistemological views, students have to construct knowledge for themselves, starting from their initial conceptions and building towards the scientific perspective.

Conceptual change, the transformation of learners' prior conceptions into more scientific conceptual understanding, is therefore a necessary part of science learning (Posner, Strike, Hewson, & Gertzog, 1982). Conceptual change has been studied extensively in science education (Amin & Levrini, 2018; Vosniadou, 2013). A large body of research has examined the relation between conceptual change and ontological classifications, epistemic beliefs, models and modeling, and communication and social interaction (Amin, Smith, & Wiser, 2014). Due to the complexity and abstract nature of many science concepts, all of those components have their influence on conceptual change in science.

Different perspectives on conceptual change have emerged over the past few decades (Amin & Levrini, 2018; Carey, 1986; diSessa, 1998; Posner, Strike, Hewson, & Gertzog 1982; Vosniadou & Brewer, 1992). The knowledge-in-pieces perspective views knowledge as consisting of fragmented pieces of knowledge, termed p-prims (phenomenological primitives), that should be re-organized and become internally coherent (e.g. diSessa, 1998). The theory change perspective advocates that intuitive knowledge is coherent and theory-like (e.g. Carey, 2009; Vosniadou & Brewer, 1992). This theory assumes that students hold presuppositions, which conflicts with the information they receive through instruction. Those presuppositions form constraints on the kinds of models that children can form during process of conceptual change. Carey (1986, 2009), who has led the development of the theory change perspective, views conceptual change as a full-scale restructuring of knowledge just like the changes that occurred to networks of concepts in the history of science. More recently, several researchers paid particular attention to the role of language in the process of conceptual change (Amin, 2009a). The different approaches to conceptual change discussed earlier did not attend to language students are exposed to.

Much of concept learning in science instruction starts with exposure to ideas formulated in language either in the teachers' speech or in the textbook. Some researchers have recently begun to address the role of linguistic input and how children learn from others (Gelman, 2009; Harris & Koenig, 2006). The focus of these studies has been on early conceptual development in children and how it is influenced by testimony, what children hear from adults. A different perspective on conceptual change

(Amin, 2009a, 2015) applies the conceptual metaphor theory from cognitive linguistics (Lakoff & Johnson, 1980). Lakoff and Johnson (1980) argued that the human conceptual system is metaphorical and that humans understand abstract ideas metaphorically through concrete ideas that are constructed from their experience and interaction with the world. So conceptual metaphor is a phenomenon in which abstract concepts are understood by mapping them onto a concrete domain of knowledge that is directly accessible and familiar because it is based on experience. There are two key ideas to this approach: 1) many abstract concepts are conceptualized metaphorically in terms of more familiar and concrete conceptual domains and these metaphorical mappings are reflected systematically in language; 2) understanding abstract ideas are ultimately understood in terms of knowledge structures that derive from sensorimotor experience such as moving objects, movement along a path and forced movement of possession. Those knowledge structures are referred to as image-schemas, these are abstractions from patterns of sensorimotor experience, and they are in turn mapped onto abstract concepts such as time. For example, 'approaching' a deadline reflects the conceptual mapping of a moment in time onto a location along a path. Another example of using sensory motor experiences to understand abstract ideas is '*Generals lead their troops to victory'*. The image -schema that grounds our understanding is the Path image schema used to show that achieving a goal is movement along a path. Since those image-schemas are analogical representations of our experiences, this understanding of abstract concepts is considered to be embodied.

Among the difficulties faced in leaning science is that many scientific concepts are very abstract and require a lot of imagination on the part of the learner to understand an idea far removed from their everyday experience. Amin (2009a, 2015) has explored the role of metaphorical expressions in the conceptual change that occurs during science. Abstract concepts are represented metaphorically in terms of image-schemas. When the image schemas used to understand scientific concepts are explored through the conceptual metaphor theory lens it will become easier to identify intuitive knowledge structures of students and the process of conceptual change. Amin argues that learners as well as scientists make use of image schematic knowledge structures like containment, possession, and movement along a path that they acquire through sensorimotor experiences. He suggests that incorrectly mapping image schemas to an abstract scientific concept could be the source of misconception for learners. '*I have got much energy in the morning*' is an example of a metaphorical expression used in everyday language. This reflects the understanding of energy as a possession. Amin suggests that "one could then say that an aspect of conceptual change is the revision of metaphorical mappings between source and target domains." (Amin, 2015, p. 977). Brookes and Etkina (2007) showed that students sometimes fail to see the limitation of a metaphor or take it too literally. They investigated the effect of metaphorical representations on university students' reasoning about energy and found that metaphors students were exposed to were incorrectly interpreted which in turn led to misconceptions.

Many studies investigated teaching and learning about scientific concepts through the lens of conceptual metaphor theory. Studies that analyzed the language used in textbooks or by learners as they explain energy in different contexts and as they solve problems revealed the image-schematic resources used to make sense of the concept of energy in different context (Amin, 2009a; Amin, Jeppsson, Haglund, & Strömdahl, 2012; Lancor, 2014a). Other studies discuss some formative assessment approaches that analyze students' metaphors to identify their conceptions (Lancor, 2014b, 2015). Brookes and Etkina (2007) demonstrated patterns of students' misconceptions that results from literal interpretations of metaphorical expressions in the domain of quantum mechanics. In their study Niebert and Gropengießer (2014) revealed that students, like scientists, used the container metaphor to describe the process of global warming, however, they mapped the structures of the container to the structures of the atmosphere differently from scientists. This analysis helped in designing activities that led students to cognitive conflict and pushed them towards more scientific conceptual understanding. Jeppsson, Haglund, and Amin (2015) revealed that attaining expertise in problem-solving involves appropriation of several conceptual metaphors.

Energy is one of the many abstract concepts in science that has many meanings in different contexts and which students encounter in their everyday talk when interacting with the outside word, even before they come across it in school. Previous studies have highlighted the effect of everyday language in students' conceptualization of the term energy (Amin, 2009a; Jin and Wei, 2014). Differences in discourse about energy in different scientific disciplines have also been identified (Hartley, Momsen, Maskiewicz, & D'avanzo, 2012; Lancor, 2014a; Lancor, 2014b). Further research showed that we rely on metaphorical projections from experiential knowledge gestalts to understand the concept of energy and this understanding is expressed using every-day and scientific language (Amin, 2009a; Amin, Jeppsson, Haglund, & Strömdahl, 2012).

In the field of biology, the energy concept is very important in the context of ecosystems (Reece et al., 2011) and particular attention is given to the flow, transfer, and degradation aspects of energy. It was found that energy flow is a challenging topic for students exhibit many alternative conceptions (Chabalengula, Sanders, & Mumba, 2011; Lin & Hu, 2003). A study by Wernecke, Schwanewedel, and Harms (2017) has only recently discussed the reception of the language of energy in ecosystems to see whether energy related metaphors used in educational contexts are adopted and used in the intended way by students in Germany (where instruction is in German, the native language of the students). It was concluded that they often are not.

Students face difficulties interpreting the language they are exposed to during science learning (Wellington & Osborne, 2001). However, in Lebanon, as in some other parts of the world, we have to keep in mind that, in addition to the challenges faced by students in learning the language of science, a foreign language of instruction is used to teach science (Amin, 2009b). Students learn in a language that is different from that used in their local communities. However, this is inevitable given the high status of foreign language use and the aim of many to specialize in scientific and technologically oriented careers dominated by international languages, most prominently English.

As presented previously, the concept of energy is an excellent example of an abstract concept of science. Since energy and ecological processes that involve energy transformation and transfer cannot be observed, they are often taught and explained using metaphorical expressions (Amin, 2020; Lancor, 2014b). Energy metaphors are an important linguistic tool for sense making, so one might ask: how are they used in biology instruction and how are they interpreted and used by English Language Learners (ELL) in a science classroom in Lebanon? There seems to be a gap in literature on evaluating the success of the use of conceptual metaphors when teaching science in a foreign language in an ELL classroom even though previous research showed that English metaphors pose difficulties for English language learners (Dong, 2004). In their study, Brookes and Etkina (2007) reported that two students, who were both native English speakers, interpreted the metaphorical phrase 'in the ground state' (referring to an energy state in a potential well) literally and not figuratively. In their conclusion, Brookes and Etkina (2007) recommended that the role of language in communicating energy concepts in science instruction should be further researched. This study investigates if Lebanese English language learners correctly interpret, and use effectively, the energy metaphors to which they are exposed in the context of learning about ecosystems. Broadly, the purpose of this study was to explore whether language is a barrier that hinders students in making meaning of academic scientific language and understanding the metaphors used to teach science in a foreign language.

Statement of the Problem

Energy is an important topic in science, and in the context of ecosystems in particular; but students often form misconceptions about energy (Wernecke et al., 2017). The development of concepts in science, such as the concept of energy, starts with ideas formulated in language. Therefore, the language practices that are taking place in the classroom have their impact on the knowledge construction process. An analysis of a vast body of textbooks, expert discourse and students' conceptions revealed the abundance of metaphorical expressions when introducing and teaching about energy in formal contexts and as resources that students draw on (Amin, 2009a; Lancor, 2014; Lancor, 2015). Although many studies have noted that there are metaphors that communicate about energy, we still don't know whether students are understanding them as intended and what are the kinds of difficulties faced, in particular, in a context such as Lebanon where students are English language learners and it was reported in previous studies that English metaphors pose difficulties for ELLs This study used the framework of conceptual metaphor to identify the energy metaphors Lebanese intermediate school students are exposed to, the metaphors that they use to make sense of energy in the context of ecosystems and the difficulties they have in understanding these metaphors. The study included school students in grade seven since the topic of energy in the context of ecosystem is assigned to this level in the Lebanese curriculum.

Research Questions

In order to describe the nature of metaphorical language of energy transfer through an ecosystem and investigate the usage and difficulties of seventh grade ELLs in a Lebanese school, this study addressed the following research questions:

1. What are the conceptual metaphors to which seventh grade students have been exposed to through their elementary school and seventh grade textbooks?
2. What conceptual metaphors are reflected in seventh grade students' writing about energy in ecosystems?
3. How do Lebanese seventh grade school students interpret metaphors of energy in ecosystems?

Significance

Several studies suggested that the metaphors in the language of science can be both helpful and can be a source of difficulty for students when using metaphor in science teaching (Amin, 2009a; Brookes & Etkina, 2007; Brookes & Etkina, 2015; Lancor, 2014b; Niebert & Gropengießer, 2014; Niebert & Gropengiesser, 2015). This study could help identify potential obstacles to conceptualization of energy, specifically in an ELL context, that resides in the appropriation of the scientific language used.

Practically, the study can help teachers in an ELL context anticipate difficulties students might face when learning about energy. Analyzing students' mappings between source and target domains and examining reception and awareness of the metaphorical expressions in learning an abstract concept such as energy suggested points of focus for classroom discussions. Learning how metaphors are understood by the students could help teachers plan better instruction and instructional designers design effective learning tools.

Theoretically, adopting a conceptual metaphor perspective might help us understand better the role that language plays in the process of learning scientific concepts, specifically the concept of energy. This study helped to highlight the linguistic patterns that reveal the image-schemas used by scientists and students in the context of learning about energy. A comparison of both helped identify a learning demand in this context.

CHAPTER 2

LITERATURE REVIEW

It is normal to have naïve beliefs and conceptions about the world prior to receiving formal education in science. What is surprising, however, is for learners to have such naïve beliefs and misconceptions even after having enrolled in high school or college courses. This raises many questions: Where do those misconceptions come from? Are traditional strategies in teaching science helping in restructuring those concepts and misconceptions? What improved teaching strategies can change the problematic beliefs and conceptions that students bring with them to class? Are their specific strategies needed for particular kinds of misconceptions? All those questions have been addressed by the field of conceptual change. An interdisciplinary area of research that has had a long history and continues to grow (Amin, & Levrini, 2018; Posner, Strike, Hewson, & Gertzog, 1982; Vosniadou, 2013a). Recently, metaphorical language has been found to be extensively used to construe the concept of energy in scientific text, students' conceptions and everyday language (Amin, 2020). This study aims to investigate whether Lebanese middle school English Language Learners are able to understand and use the metaphors they are exposed to when taught about energy in the context of learning about ecosystems.

The first section of this literature review will address the different perspectives on conceptual change and the nature of naive knowledge students bring to class. A review of studies that investigated the role of language in learning science and its effect on the learning process and concept development will be presented in the second section. The role of metaphors in supporting and hindering understanding the concept of energy is specifically highlighted, using the framework of conceptual metaphor. The focus in the last section is on research investigating English Language Learners (ELLs) concept learning and the challenges of teaching and learning English metaphors to ELLs in the context of English language instruction.

Conceptual Change in Science Education

Conceptual change is a process of knowledge development that requires changes in the content and organization of existing concepts. Researchers in science education, cognitive science and developmental psychology are interested in how conceptual change occurs. This research helps educators understand the process of learning, and informs the design of instruction in class rooms. To understand this process of conceptual change one could start from the prior conceptions of students and examine the nature of their uninstructed knowledge. There is a vast literature on conceptual change, a process considered challenging in science education. Since conceptual change is fundamental to science learning, where many of the concepts students are expected to learn are complex, abstract and counter-intuitive, science education researchers have proposed various theories of conceptual change. These theories have led to different approaches to design of curricula and instruction (Amin, Smith, & Wiser, 2014; Carey, 1986; diSessa, 1998; Posner, Strike, Hewson, & Gertzog 1982; Vosniadou, & Brewer, 1992).

Theories of Conceptual Change and Conceptual Change Instruction

There are different perspectives on conceptual changes. Posner, Strike, Hewson, and Gertzog (1982) advocated a theoretical framework, often referred to as “the classical approach”, to conceptual change. It became a leading paradigm in guiding research in science education in the years that followed. In this framework misconceptions are incorrect alternative theories that have to be replaced in favor of scientific conceptual understanding. Posner et al. (1982) derived an instructional theory from this perspective that suggests that students should experience similar situations scientists go through in order to develop their scientific conceptions. Four conditions have to be met before conceptional change can happen. The students, like scientists, have to first be dissatisfied with their existing conceptions. Secondly, the new scientific conception has to be intelligible and well understood. Thirdly, the new conception should be seen as plausible and reasonable; and last of all it should be seen as fruitful and applicable to other contexts. When this happens, alternative conceptions will be replaced by the correct scientific view just as scientists came to accept new ideas.

This classical approach to conceptual change was opposed by several researchers who were interested in characterizing more carefully naive conceptual structures. A line of research conducted by Vosniadou and colleagues was concerned with describing the development of knowledge in many fields such as astronomy (Vosniadou & Brewer, 1992) and mechanics (Ioannides & Vosniadou, 2002). The development of the framework theory approach to conceptual change was a result of such research. Vosniadou (2013a) states that ‘at the heart of the framework theory is the idea that young children start the knowledge acquisition process by developing a naïve physics that does not consist of fragmented observations but forms a relatively coherent explanatory system – a framework theory’ (p.13). The framework theory describes the naïve conceptions children form from their early everyday experiences with the world as preconceptions. Misconceptions are often formed as students use their preconceptions to interpret the scientific concepts they are exposed to at school.

Vosniadou (2013a) argued that intuitive knowledge is coherent and theory-like, but maintains that it lacks the systematicity and abstractness of scientific theories and that children lack the metaconceptual awareness of their framework theory. Vosniadou describes children as having a pre-existing framework theory which is a result of their observation of the world. This theory assumes students hold ontological presuppositions (e.g. that unsupported things fall down) which conflicts with the instructional information they receive (e.g. that the Earth is a sphere). Those presuppositions form constraints on the kinds of models that children can form. According to Vosniadou children tend to give systematic answers that reflect the intuitive concepts of the theory they hold.

Unlike the classical approach to conceptual change, the framework theory does not consider misconceptions held by students to be incorrect and doesn't assume that they can be simply replaced by the right scientific concepts. Instead, a considerable restructuring of knowledge is often required. Instruction is designed in a way that leads to restructuring of pre-existing understandings into more coherent scientific theories in science classrooms. In one study Diakidoy and Kendeou (2001) analyzed the result of implementing instruction that made students aware of their initial conceptions about the shape of the earth and the day and night cycle. The instructional procedure consisted of a collaborative problem-solving activity and whole-group discussion where students were given the chance to question their initial beliefs and experience the plausibility and explanatory power of the scientific theories; together these strategies fostered conceptual change. The study demonstrated that instruction that targeted students' ontological presuppositions could be effective in supporting conceptual change.

The framework theory approach is similar to "theory-theory" approaches, where concepts are understood as embedded in larger theoretical structures that constrain them and students' conceptions need to be transformed through instruction and not simply replaced. However, the two theories differ in that the framework theory advocates conceptual change as slow and gradual, unlike the theory-theory approach which gives more emphasis to fairly radical changes from one coherent theory to another. In Carey's (1986, 2000) 'theory-theory' approach, conceptual change in science learning is seen as similar to knowledge restructuring in the history of science.

The 'theory-theory' approach to conceptual change can be understood as guided by conceptual resources and a variety of bootstrapping mechanisms that enable restructuring. Students' beliefs are formulated in terms of concepts that differ from that of the scientific perspective (Carey, 1986, 2000). Conceptual change involves a shift from one theory to another and requires a change in the underlying concepts in the intuitive theory used to understand the beliefs. In bootstrapping there is an analogical transfer of information such as conceptual mapping between domains of knowledge that would lead to such knowledge restructuring. A characteristic at the heart of the bootstrapping process is when students draw on ideas clearly represented in one context to help them restructures ideas in another.

Other researchers have not agreed with previous perspectives to conceptual change that considered misconceptions to be incorrect or coherent and theory-like. Andrea diSessa argues for the knowledge-in-pieces perspective in which the intuitive knowledge children hold is not consistent and has no theory-like nature (diSessa, 1988). This knowledge, in his view, consists of fragmented pieces of knowledge that should be re-organized and become internally coherent to bring about explanations. diSessa called those knowledge structures, phenomenological primitives (or p-prims). Those p-prims are abstraction from sensory motor experiences. An example of a p-prim is *Force as a Mover* which is an abstraction of a throw. According to diSessa many p-prims are needed to fully characterize understanding of physical situations. Different p-prims are triggered when reasoning in different contexts. Different situational cues trigger the application of different p-prism in the reasoning of novice and experts.

From a knowledge-in pieces-perspective diSessa suggests that students learning therefore, is not very far from their current state of understanding. When designing instruction, one should start with experiences that generate and support pre-instruction knowledge. Microworlds could provide artificial realities similar to students' experiences (diSessa, 1988). By manipulating the right set of p-prims in this interactive environment students could develop new scientific understanding. Microworlds provide the artificial realities that interacts with students' idea and start with experiences that students can manipulate in order to deepen their scientific understanding. White (1993) proposed that the computer can serve as a conceptual tool that will allow students to observe, hypothesize and test their hypothesis in an attempt to build on their prior knowledge. White's study focused on the field of mechanics and presented, for example, how students can reorganize their knowledge of a force as a mover into a more scientifically approved conception such as forces causes acceleration. The students here can move the dot on the screen using a joystick. Students will be able to experience that the push of their hand on the joy stick made the dot change its motion. They see on the screen the history of the position of the dot that shows how the impulse (force) exerted affects the motion and speed of the dot.

The Concept of Energy and Conceptual Change

Big ideas such as energy, matter, scale, equilibrium, interaction, evolution, forms and functions are essential unifying concepts that play an important role in the core theories and in the principles of science (AAAS, 2011; National Research Council, 2012). The concept of energy is a common concept that students come across in all disciplines of science including biology, chemistry and physics (AAAS, 2011; College Board, 2009; CRDP, 2020). However, there is a difference in how the concept of energy is taught in different scientific domains. For example, in physics, students are taught about energy being ‘conserved’ while the discussion in biology is about a percentage of energy being ‘lost’ as a result of different interactions in an ecosystem. Scientists are aware of the fact that the energy of physics is the same as the energy of biology but the analytical methods used in tracking energy changes differs between disciplines. Students are not aware of this fundamental similarity. Therefore, energy is one of those crosscutting concepts that the *Framework for K-12 Science Education* (National Research Council 2012) considers necessary for students in connecting knowledge from different disciplines of science to build a scientifically based view of the world and this is the reason for the focus on energy in this study.

Students however, start learning about energy and constructing knowledge about it from their interaction with the world long before they enter school. This intuitive knowledge may not be consistent with the scientific view of energy. Therefore, there is an academic need to develop the scientific view of energy in different scientific domains (Eisenkraft et al., 2014). As citizens, students will have to make informed decisions concerned with environmental, economic and social issues involving energy (Bybee, 1991).

In the U.S. the *Framework for K-12 Science Education* (National Research Council 2012) and the *Next Generation Science Standards* (AAAS, 2011) highlighted that the concept of energy is one of those concepts that has to be taught as a crosscutting concept in addition to disciplinary core concepts. (AAAS, 2011; Chen, Scheff, Fields, Pelletier, & Faux, 2014; College Board, 2009; National Research Council, 2012). In the Lebanese science curriculum, the general topics of content for elementary level taught are stated under six themes (CRDP, 2020). One of the themes that appears in all intermediate classes is *Matter and Energy*. In the science curriculum of intermediate level, the concept of energy is addressed in different themes covered among all three sciences. The ability of characterizing and modeling energy could be taught as cross-cutting concepts across all sciences and engineering (National Research Council, 2012). The challenge of teaching energy as a cross-cutting concept had to be addressed by science education research communities (Eisenkraft et al., 2014). When energy is taught as a cross-cutting concept, students, scientists and engineers will be better equipped to think about cross-disciplinary problems that are arising in our world.

In addition to energy being a core concept of science and a cross-cutting concept, energy teaching and learning also goes beyond the canonical scientific knowledge. Energy is rooted in society and interacts with culture and politics (Liu & Park, 2014). Students should understand the role energy plays in our lives so that they can make decisions and solve energy-related problems. Driver and Millar (1986) argued that in order for students to comprehend and appreciate the relevance of energy to society, they have to gain a complete understanding of the concept of energy. The aim of teaching energy should be to promote meaningful appropriation of this domain of knowledge to ensure discussion and more involvement in energy issues related to our lives and planetary emergencies (Bybee, 1991; Doménech et al., 2007; Morresey & Barrow, 1984).

To ensure effective learning about energy, teaching practices should pay attention to several important aspects and characteristics of energy (Doménech et al., 2007; Neumann, Viering, Boone, & Fischer, 2012; Nordine, Krajcik, & Fortus, 2010). There are four aspects of the concept of energy that students must learn: energy transfer, energy transformation, energy conservation, and energy degradation. Central to the concept of energy is that it is neither created nor destroyed. Chemical reactions and physical transformations take place but the quantity of energy in a given system remains unchanged. The changes that occur to the system are a result of energy exchanges taking place. This exchange takes place through energy transfer as well as energy transformations between different forms of energy. Through this exchange energy will be spontaneously degraded – i.e. becomes less available to do work.

While all agree on these four aspects of the abstract concept of energy, energy still has many meanings in different scientific contexts and in everyday language and this makes it hard to define (Lancor, 2014a; Quinn, 2014). In their study, Hartley, Momsen, Maskiewicz, and D'avanzo (2012) reported that biology and chemistry textbooks define energy in different ways. Some biology and chemistry books define energy as the capacity to do work. Three biology textbooks stated that energy can promote or do work and one biology book and one chemistry book described energy in relation to heat transfer. Hartley et al. (2012) showed that there was a clear focus on movement and transformation of energy in biology textbooks and less on conservation of energy, the first law of thermodynamics. The textbooks did not highlight the interrelationships between biology, physics and chemistry and they support rote memorization of definitions which hinders students in developing systemic thinking and problem-solving skills. It has been suggested that a good way to point out to students the differences in meanings and definitions of energy across disciplines is to discuss those differences explicitly (Quinn, 2014).

In an attempt to understand intuitive ideas that hinder students from developing a scientific understanding of energy, Jin and Wei (2014) looked up colloquial meanings of energy, through examining several dictionaries. In summary, the linguistic analysis first showed that the informal view associated energy with life, feelings, and emotions while the scientific view differentiates energy from psychological entities. Second, energy in the informal view is treated as a cause while in the scientific view it is a constraint. As Jin and Wei discuss, students encounter energy in their daily experiences and daily discourse before being introduced to it academically. They form their own conception about it which might contradict the scientific point of view. Thus, a new challenge arises in addition to the challenges of teaching energy as a disciplinary core concept and a crosscutting concept across scientific domains. Teachers have to also help students use the resources they have, related to the concept of energy, to understand the scientific concept of energy.

The discussion above showed that energy is construed differently in different disciplines of science. This study will focus on energy understanding in the context of biology. Opitz, Blankenstein, and Harms (2017) provided an analysis of students' conceptions about energy in biological context. It was reported that students had more difficulty explaining the notion of energy degradation and energy conservation across all grade levels, compared with their understanding of energy forms or sources and transformation which turned out to be easier for students. There appeared to be incoherence in understanding of individual energy aspects such as irreversibility of energy degradation or the conception of energy consumption and loss in specific contexts. The students' concepts were not clearly connected to a biology-specific understanding; they were mostly based on a discipline-general understanding of energy.

The progression in using more acceptable conceptions and less inaccurate alternative conceptions of energy was evident across grade levels. Optiz et al. (2017) emphasized that this reflects an increase in sophisticated use of language by older students and their development of new conceptions.

Chabalengula et al. (2011) explored first year university biology students' understanding of the concept of energy in biological contexts. Students had to explain their understanding of energy in biological contexts and state whether energy is present in given diagrams and in which forms. The findings revealed that most students simply recite the laws and definitions as those definitions are easily rote-learned. It was found that students had difficulties applying energy conservation principle to biological phenomena. The results also revealed a very loose understanding of energy conversions and transfer by most students.

A study by Lin and Hu (2003) revealed that energy flow is a challenging topic for students which involved many alternative conceptions. The participants in the study were seven grade students. The task given to the students was to construct a concept map with the title 'Energy Flow and Matter Cycling.' Energy flow and matter cycling have to be represented in the map in the context of the food chain, photosynthesis, and respiration. The twelve items that had to be included in the map were photosynthesis, respiration, producers, consumers, decomposers, matter, energy, oxygen, water, carbon dioxide, glucose, and sunlight.

Students' understanding of energy flow and matter cycling was analyzed through the concepts they included and the relationships they set down in their maps. The students showed weak understanding of the concepts and they did not show any understanding of the inter-relationships between the concepts in their maps. Although the study was not measuring directly knowledge of matter and energy but it suggests that the weak understanding of this physical knowledge makes it hard for students to understand the flow of energy and matter between the living and non-living world.

The studies reviewed so far show that there is difficulty in conceptualizing certain aspects of energy in the context of biology. In biology education the energy concept is targeted the most in the context of ecosystems (Reece et al., 2011) and more emphasis is placed on the flow, transfer, and degradation aspects of energy in the context of ecosystems (Lancor, 2014a, 2014b). This line of research guided the focus of this study to be specifically on energy in ecosystems.

Learning About Scientific Concepts Through Language

Many conceptual change theories have not really incorporated much attention to the role that language plays in the process of concept learning (Amin, 2009a). However, this is important because much of what we learn cannot be learnt directly through interaction with the world but has to be learned through linguistic input. Researchers who have made this argument are those who have worked on learning through testimony, such Gelman (2009), Harris and Koenig (2006), and Harris, Pasquini, Duke, Asscher, and Pons (2006). These authors have argued that much of children’s concept learning involves assimilating what they receive through testimony. They have addressed questions like ‘What does one end up learning from the language they receive?’ and ‘How does language guide and lead children to learn?’

In this section, I begin by reviewing studies that shed light on the language children are exposed to in early childhood and examines the trust children have in testimony from others around them. The next sub-section will deal with children’s encounter with the formal language of science in academic settings. Characteristics of the language of science and challenges faced in interpreting and making meaning of science text and concepts will be presented. However, in addition to the language communicating the results of science, the language of science is also characterized by the use of figures of speech that, it is assumed, aids in developing conceptual understanding. In the last sub-section, the focus will be specifically on the role of metaphorical expressions in the teaching of abstract scientific concepts. The contributions of the conceptual metaphor theory to the study of conceptual change will be discussed and then research specifically targeting metaphor use in the learning and teaching of the concept of energy in science will be presented.

Learning Through Testimony in Early Childhood

Recently there has been a growing research interest in the nature of the linguistic input children are exposed to and how they learn from others (Gelman, 2009; Harris & Koenig, 2006; Harris, Pasquini, Duke, Asscher, & Pons, 2006). This body of research sheds light on the early conceptual learning of children and how they learn about unobservable entities and change their beliefs about these entities based on what they are told.

Studies such as Harris et al. (2006) and Harris and Koenig (2006) investigated children’s reliance on the testimony of people to learn about unobservable scientific and spiritual entities. They define testimony as the language used to make credible assertions about entities in the world that can be treated by the listener as reliable evidence for the truth of those assertions. Harris et al. (2006) investigated the beliefs of children, ranging between 4 to 8 years, about the existence of different types of entities. The entities were real entities (such as cats and trees which are visible to everyone), scientific entities (such as gas and germs that cannot be seen but whose existence is presupposed in everyday discourse), endorsed entities (such as the Tooth Fairy and Santa Clause whose existence is endorsed in discourse with children), equivocal beings (such as monsters that are not endorsed in discourse with children), and impossible entities (such as monsters, which no one believes in).

The results showed that children affirmed the existence of real entities and scientific entities and they affirmed that other people believed in their existence too, while they denied the existence of impossible entities. Children also asserted the existence of endorsed entities and denied the existence of equivocal entities. This belief in the existence of invisible scientific entities and endorsed entities is not due to their first-hand encounter with them, since they are unobservable, but rather to the discourse that they hear from people around them in their everyday lives. Children admitted that they knew what real entities looked like but when asked about the properties of scientific entities they admitted that they did not know what they looked like and sometimes gave a casual sequence such as, ‘if there was no oxygen we would die’ as an explanation to existence of scientific entities. These findings support the claim that children accept the testimony of adults about unobservable entities that are impossible for them to observe when developing concepts of them.

In addition to the evidence summarized above, Harris et al. (2006) found that children also distinguished between scientific entities and endorsed entities. Children were more confident in their assertion of the existence of scientific entities than endorsed entities. This further supports that children’s beliefs are not only influenced by testimony but they are even influenced by the level of testimonial support that they receive from trusted sources such as their parents.

Harris and Koenig (2006) present similar findings to Harris et al.'s (2006). Children were found to accept testimony about unobservable entities and processes and use it to construct a coherent, if not scientific, conception of the role of the brain, the shape of the earth, or the biology of life and death. As a result of these finding they raised an important question. If children are sensitive to testimony from trusted sources about unobservable entities, then why do they resist changes to conceptions they bring with them to school? In the course of receiving instruction about some concepts that do not align with their beliefs, such as the shape of the earth, children are said to resist the scientific point of view and hold on to their own naïve conception or to construct alternative synthetic mental models of the earth constrained by their prior conceptions (Vosniadou & Brewer,1992). Harris and Koenig (2006) suggest that although children's understanding of the shape of the earth develops slowly and gradually into a scientific conception, they still manage to integrate people's testimony about the shape of the earth with their first-hand experience of the earth being flat; the result is a coherent but inaccurate synthetic mental model.

Children learn through first hand experiences and from social interactions with people around them. Harris et al. (2006) and Harris and Koenig (2006) describe the effect of social interaction, in the form of testimony, on concept development in children. Gelman (2009) takes the focus on the role of language in concept learning even further to examine what kinds of information are communicated to children by means of language, and how it is interpreted.

Language has a powerful effect on modifying concepts Gelman argues. Lexicalized concepts, where a concept is represented by a word in a given language, can affect children's initial conceptions. Children infer similarities and differences from labels given to items and this in turn influences concept development. For example, young children treat objects that receive the same noun label as having similar properties even if it was not obvious- i.e. when told that a blackbird feeds its young mashed food, children will assume that another bird like a flamingo does so too and not a bat. Distinct labels will encourage children look for differences. Gelman also points out that speakers of different languages may notice aspects of their experience and categorize the world differently. She argues that such differences are due to covert categories, categories inferred based on the contexts of language used, and implicit categories, those cases in which a meaningful category is implied by speakers' language use. An example of a covert category is proper female names such as Sally, Elizabeth, and Diana. They are considered as such, even though nothing explicitly marks them alike, because each is co-referential with the pronoun 'she'. However, words in French (soup, table, bank) that receive the same gendered pronoun are not labeled as instances of the same category (not overtly considered female) and are considered an implicit category. Gelman was interested in whether convert and implicit categories can guide children's reasoning. She explains how Yucatec Mayan speakers can give the same name to different-shaped things like banana tree and banana leaf and as a result group these things together according to substance. English speakers, on the other hand, are more likely group items according to shape. This differentiation is due to the different language patterns found in the two languages.

What has been reviewed so far implies that children's concepts are not wholly perceptual, neither are they totally dictated, and they are influenced by the language to which children are exposed. Children's learning is substantially shaped by others through the ideas, categories and beliefs conveyed through language. An understanding of the nature and structure of the different linguistic resources made available to children is therefore essential to understand concept learning. An understanding of the nature and structure of the different linguistic resources made available to children in the context of formal science learning through written text and discourse will be examined in the next sub-sections.

The Language of Science and Formal Science Learning

There is more to science than just experimentation and field-based work. This work is surrounded and complemented by the activity of communication which is defined by mental activities such as writing, reading and speaking (Phillips & Norris, 2009). The language of science is characterized by its organized structure. Scientists engage in a variety of speech acts such as reporting, motivating, describing, arguing, explaining, and challenging alternative interpretations. Interpreting scientific text is therefore challenging, and Phillips and Norris linked this to the language of school science.

An important linguistic factor that is first encountered by students in the science classroom and that might stand at odd with the students' everyday discourse is the uniqueness of the discourse of science practice. Certain language frameworks and genres are particularly important during communication in the context of science practices. The students in a science classroom are introduced to unfamiliar discursive patterns and practices of science (Kelly, 2014).

Doing science and developing scientific literacy is not achieved through observations and collecting data alone. To develop scientific literacy and become a member of the community of scientists, students should also understand the social practices of the community which are mediated through language (Carlsen, 2013). It is important for students to develop interest in reading about science, to read critically, and present claims grounded in argumentation and evidence. Such practices are all carried out through the discourse practices of the community of scientists and through the language of science. Science knowledge construction is based on the relationships built between the language baggage the students bring from home and the instructional language they receive in school (Carlone, Johnson & Eisenhart, 2014). A closer look at the role of language in science education, especially when teaching about abstract concepts, is therefore necessary.

The language of school science is presented in school text as either expository or narrative which does not include argumentative texts. Students are mostly exposed to facts and conclusions and, when asked to read or write, their goal would simply be to read words correctly or rephrase passages. Phillips and Norris (2009) showed that there was a pattern of weakness in the reading ability of high school and university science students. They interpreted what they read in a literal manner and gave it more certainty than the author intended. Weakness was also detected in students' interpretation of the role of statements in scientific reasoning.

Students hold a simple view of reading which leads to the challenges mentioned previously. Less accomplished readers and readers dealing with text outside their areas of proficiency will face difficulties in interpreting science text. This is why Phillips and Norris argued that reading is best done as an inquiry process. Students should be able to link their background knowledge with what they are reading to be able to infer meaning from text. Reading could be a constructive process that involves mental activities like exploring meanings assumed, implied and justified by the text. This will, in turn, lead to a constructive process in developing scientific concepts.

Research has shown that additional challenges faced in learning the language of science include the abundance of scientific vocabulary (Groves, 2016), the abstract nature of science concepts, new words that are taught in familiar and sometimes unfamiliar contexts, words that have different meanings in academic science language and everyday language (Wellington & Osborne, 2001) and the fact that science involves many representational systems, not just language (Osborne, 2002). The fact that scientific language is complex and multifaceted supports the idea that it should be targeted in ways that enhance students' ownership of important words and concepts (Hayden, Baird & Singh, 2020).

Wellington and Osborne (2001) state that science teachers are also language teachers and have to be aware of the difficulty presented by technical words such as *energy*, *power* and *work* that have different meanings in science than their meanings and use in everyday language. Another challenge of teaching the language of science is to teach the academic of language of secondary education that includes words, like interpret, infer, evaluate and modify, which are only used in exam papers and academic text and seldom heard in playgrounds, gatherings and games.

Although teaching of technical words and polysemous words are challenging not all communications of ideas and concepts in science are verbal. There is usually a combination of words, pictures, videos, models, graphs, equations and charts to convey meanings in science and those components complement each other (Wellington & Osborne, 2001; Osborne, 2002). All the different semiotic signs of science language have to be understood, integrated, modified and translated in the students' conceptual systems through language. As a result of this complexity of the language of science, research on the role of language in science education reduced importance of language as a means of transmitting information and emphasized its role as an interpretive system of sense-making.

The language of science is not transparent and straight forward as some teachers might think. The abstractness of many science concepts makes them harder than concrete concepts to be understood and therefore specific instructional tools are required to help students understand them. Useful forms of representations, illustrations, and powerful analogies are extensively used as instructional strategies to make concepts comprehensible to students (Won, Yoon, & Treagust, 2014). Conceptual understanding can be brought about by the use of figures of speech, such as metaphor, which facilitates restructuring of preconceptions for the learning process (Clement, 2009). More fundamentally, it has been argued that the human conceptual system is metaphorical in nature (Lakoff, & Johnson, 1980) and as a result many science education researchers have been interested in studying the role metaphors and analogies in teaching and learning science concepts (Amin, Jeppsson & Haglund, 2015; Aubusson, Harrison, & Ritchie, 2006). This will be the focus of the next subsection.

Metaphors in Science and Science Learning

In this sub-section, I start by giving a brief account of the conceptual metaphor theory, the theoretical perspective that has guided the interpretation of metaphor use in science education and specifically in conceptualizing the concept of energy. Then research on how metaphorical language can be an additional resource but also a challenge for conceptual change will be reviewed. Studies that have looked into students' conceptions, conceptual development, and design of suitable instructional tools through the lens of conceptual metaphor theory will also be summarized. I will conclude with a summary of studies that examine metaphorical expressions construing the different aspects of the concept of energy in pedagogical discourse. The studies revealed a line of evidence that supports conceptual metaphors' contributions to the conceptualizing and reasoning about energy and entropy. The findings of the studies also expose the role of everyday metaphors in shaping students' naïve conceptions of energy and some overlap in the use of metaphor in lay and scientific contexts. Several studies analyzed conceptual metaphors as implicit conceptual resources students draw on as they develop a formal understanding of the concept of energy in different contexts. This review of those studies illustrates how the use of metaphorical language both hinders and supports the learning of the concept of energy.

Conceptual Metaphor Theory. Metaphors provide a simple way to conceptualize abstract ideas in terms of more familiar, concrete ideas (Lakoff & Johnson, 1980). From the perspective of the theory of conceptual metaphor, many concepts in our conceptual system are understood in terms of metaphors. The mapping that takes place between the source domain and the target domain reflects how thinking mechanisms lead to the formation of new meanings through language. Conceptual metaphor theory consists of three basics claims that were made by Lakoff and Johnson (1980). The first is that a lot of our conceptual system is understood metaphorically; abstract ideas are understood in terms of more concrete ones. The second is that many of the concrete source domains are knowledge structures that emerge from experience. The third is that all the mappings are reflected in language.

With regard to the first claim, Lakoff and Johnson argue that abstract concepts such as time, ideas, and emotions are conceptualized metaphorically in terms of concrete concepts like *space*, *food*, *motion*, and *objects*. For example, a conceptual metaphor might project the idea of a substance onto something that would not be literally understood to be a substance, such as saying that you are '*trying to get an idea across by putting it into words*.' In this example, we would be making use of the conceptual metaphors Ideas are Entities and Words are Container. However, a metaphor that highlights some aspects of a concept might implicitly hide others. Every metaphor conceptualizes only certain aspects of the abstract concept, that's why many conceptual metaphors are used to capture different aspects of an abstract concept.

Conceptual metaphor theory is a theory about embodied cognition. Our abstract ideas are grounded in knowledge that comes from physical experience. Key abstract concepts that structure our understanding of events such as *time*, *cause*, *change*, *state*, and *purpose* are understood in terms of knowledge structures that derive from sensorimotor experience referred to as image-schemas, which are abstractions from patterns of sensorimotor experience (e.g. *obstacles to movement along the path*, *movement of possessions*, and *containment*). Lakoff (1990) argued that metaphorical expressions reflect a systematic mapping between domains of knowledge. For example, what Lakoff calls the Object Event Structure Metaphor includes sub-mappings such as State is a Possession (e.g. *I have a temperature*), Change in State is Movement of a Possession (e.g. *I got his cold*), and Caused Change in State is Transfer of a Possession (e.g. *The news pushed me over the edge*). In the Location Event Structure Metaphor, on the other hand, the state is the location and the entity is changing states and moving. The sub-mappings of the Location Event Metaphor are State is a Location (e.g. *I'm in love*), Change of State is Movement (e.g. *I fell into a depression*), and Caused Change of State is Forced Movement (e.g. *He pulled me out of this grim mood*).

Some metaphors have strong physical basis and are considered universal concepts, such as More is Up; while others depend on culturally relative activities and experiences. How people understand metaphorical concepts depends heavily on the different cultures and different meanings across cultures. People have their own different experiences, and metaphors are grounded in those experiences. The cognitive metaphorical theory proposes metaphors as a way of thinking and conceptualization embedded in concrete experience. Interpretations made to understand or explain the meaning of something can be made through different language-embedded construals. Metaphorical construal plays an important role in making meaning since it is a construal of experience encoded in language that helps in the conceptualization of abstract ideas.

The discussion presented above brings us to the third claim made by Lakoff and Johnson. All mappings are reflected in language as the example above illustrate. Amin (2009a) argued that exposure to and appropriation of the metaphorical expressions in language aids in the transfer of the relational structures from one knowledge domain to another. He also suggested that metaphorical construal implicit in everyday language could lead to the development of naïve conceptions. This claim will be elaborated on in the next sub-sections.

Conceptual Metaphor and Conceptual Change in Science. As we have seen, research on conceptual change seeks to understand students' conceptions before instruction, to compare those to the scientific understanding that will be the target of instruction, and to understand the process of conceptual change. In addition, this research then leads to recommendations of how to teach in a way that can support conceptual change. Conceptual metaphor as a framework has been used to address those aspects of conceptual change. Amin (2009a, 2015) explains how the theory of conceptual metaphor can be applied to the theory of conceptual change. He argues that the different goals of conceptual change - which are characterizing learner and scientist conceptions, identifying obstacles to learning, understanding the process of conceptual change, and designing productive pedagogical strategies that could achieve conceptual change can be met using a conceptual metaphor perspective. Amin (2015) reviewed a literature to illustrate how each of those goals is addressed by the conceptual metaphor approach.

Several studies analyzed scientists' and students' language from a conceptual metaphor perspective (Amin, 2009a; Brookes & Etkina, 2007; Lancor, 2014a; lancor, 2015; Niebert & Gropengiesser, 2015). The findings were then compared to answer the following questions: (1) How do the source domains used by scientists and students to ground their understanding of some domain compare? (2) Do scientists and learners differ in the contexts in which they invoke particular source domains to metaphorically construe a scientific concept? (3) When the same source is selected to construe the same abstract concept, does the mapping differ?

Amin (2015) reviewed several studies that demonstrated how using the theory of conceptual metaphor to describe scientists and learner conception helps in identifying obstacles to the process of conceptual change. The findings of Brookes and Etkina (2007, 2015) revealed that scientific language dealing with quantum physics, forces, and energy included implicit metaphors and that students' misconceptions mirror those ontological metaphors in the language they are exposed to during instruction. The explanation Amin provides is that this could be because they map too much of the source domain implicit in the scientific language. In Amin (2009a) when the two sets of metaphorical mappings in everyday and scientific language about energy were compared, a great deal of overlap in the use of source domains to construe energy was found. When the concept of energy was analyzed in everyday English, students' naïve conceptions of energy were found to correspond to metaphorical construals implicit in everyday language. Niebert and Gropengiesser (2014) identified metaphors in scientific text that are important for understanding the greenhouse effect and described the metaphorical patterns used by students and scientists. They showed that scientists used the container metaphor, where the container resembles the atmosphere in an attempt to describe the flow of radiation into and out of the atmosphere. The analysis revealed that students also used the container metaphor to describe the process of global warming; however, they mapped the structures of the container to the structures of the atmosphere differently from scientists.

The conceptual metaphor theory helped analyze how scientific concepts are also understood. When the image schemas used by students and scientists are identified and compared a broader goal of understanding conceptual change can be achieved. The intuitive structures involved in the learning process can be identified and learning challenges can be described. Amin (2015) suggested that analyzing the source domain, target domains and the mappings done by students and scientists contributes to understanding the process of conceptual change.

Some mappings, as Amin (2015) presented, were found to be similar to those in scientific language. Others involved mapping the wrong source domain or incorrect mapping of the right source domain. This leads to knowledge being consistent with the scientific concepts or it might be the source of misconceptions (Amin, 2015). Those misconceptions will have to be revised through the process of concept learning. Amin (2015) highlights ‘that an aspect of conceptual change is the revision of metaphorical mappings between source and target domain.’ (p. 977).

The literature review Amin (2015) presented showed that scientists and learners rely on image schematic knowledge structures such as possession, movement of possession, movement along a path and containment as source domains. Those image schemas are assumed to originate in the sensorimotor experiences. Hence the learning of scientific concepts through correct mapping to those image schemas is equivalent to reorganization of phenomenological primitives in conceptual change literature (diSessa, 1988).

Finally, Amin (2015) points to the fact that those conceptual metaphors are reflected in language which implies that language could be considered to have a role in conceptual change. Learners conception were found to mirror conceptual metaphor found in everyday language (Amin, 2009). Literal interpretation of metaphors used in scientific text also lead to misconception development form the side of learners (Brookes & Etkina, 2007). Conceptual metaphors were prevalent in science language and everyday language. This serves as evidence that concept development requires the appropriation of metaphorical construal implicit in language (Amin, 2009).

Metaphors of Energy and Conceptual Change. As discussed previously, energy is an abstract and complex scientific concept that has different meanings in different contexts. Students are already exposed to the concept of energy through everyday discourse which makes them form their own conceptions of energy that may not be consistent with the scientific perspective. Research has demonstrated that we rely on metaphorical projections from experiential knowledge gestalts to understand an abstract concept such as energy and those projections are revealed in verbal metaphors found in every day and scientific language (Amin 2009; Lancor, 2014a; Lancor, 2014b; Lancor, 2015). Several studies explored the scientific language of textbooks (Amin, 2009;

Amin, Jeppsson, Haglund, & Strömdahl, 2012; Lancor, 2014a) and scientific discourse used during problem-solving (Jeppsson, Haglund, Amin, & Strömdahl, 2013) and analyzed the metaphorical expressions that construe energy and related concepts like entropy. Other studies analyzed the language used by learners in classroom settings when explaining natural phenomena to reveal the image schematic resources they have (Lancor, 2014b, 2015) and the source of misconceptions held by students (Brookes & Etkina, 2015). Amin (2020) brought together research on metaphors used in the context of science, learning, and instruction to conceptualize the concept of energy.

Amin (2020) first presented and discussed how the conceptual metaphor theory can be used to understand the systematic use of implicit metaphors to conceptualize energy in science textbooks and in the oral communication of scientists. The metaphorical use of the term energy in scientific text was reported in several research studies. Amin (2009a) reported the use of metaphorical expressions reflecting the Object Event Structure conceptual metaphor and the Location Event Structure conceptual metaphor (discussed in the sub-section on conceptual metaphor theory) in the textbooks analyzed. Energy was referred to in the context of human technology, the consumption of food and other energy intake, and energy in relation to human activity. Sub mappings that constitute the Object Event Structure metaphor were found to construe energy exchange where energy was represented as possessed, lost or gained. Energy was also understood as a content in a container or as a resource. Forms of energy and energy transformation were construed in the Location Event Structure conceptual metaphor. The forms of energy are construed as containers (e.g. Forms of Energy are Locations). The transformations are presented as movements in and out of the containers. Different metaphorical mappings were found to account for the conservation of energy. One sub-mapping that quantifies energy was Energy State is Amount of Substance and another one was Energy States are Locations (e.g. *They are in the lowest energy states*).

Additional evidence for the role of metaphorical mappings to construe the concept of energy was reported by Lancor (2014a) who argued that definitions of energy alone are not enough to provide useful language for discussing systems in terms of energy. She applied the conceptual metaphor theory to examine concepts of energy in textbooks of different science disciplines. It was evident that some characteristics of energy were emphasized in one discipline more than the other. Energy flow language was found to be prominent in biology textbooks. Conservation of energy and transfer of energy were reflected extensively in metaphorical language in physics and chemistry textbooks. The substance metaphor was the most common metaphor implied by the discourse analyzed to explain energy as a tangible substance that can flow, can be carried, can be stored, can be lost or added, can be quantified, and can change form.

No one metaphor, however, was found to incorporate all characteristics of energy. One metaphor can highlight one aspect of energy but it obscures any explanation of others. For example, Energy Flow could highlight energy transfer, while downplay transformation of energy. In addition to the substance metaphors discussed, Lancor mentions a common metaphor used in chemistry and biology texts that does not treat energy as a substance but rather as a process and makes an analogy between chemical energy and gravitational potential energy. Those textbooks refer to the transformation of potential energy to kinetic energy to explain the process of energy transformation in chemical reactions. The studies presented by Amin (2020) reveal the power of the substance metaphor in the conceptualization of energy exchange, transformation and conservation.

Energy transfer, transformation and conservation were prevailing in the scientific contexts reviewed till now; however, the aspect of energy degradation is captured in the domain of entropy. A number of conceptual metaphors that construe entropy and the second law of thermodynamics were found to be common across different chemistry and physics textbooks (Amin et al., 2012). One of the findings directly related to energy, is the application of the metaphor Change of State is Transfer of a Possession to understand change of energetic states. The change of energetic state that involves the release of heat is a feature of spontaneous processes.

This body of research discussed so far highlighted the systematic use of metaphoric expressions in different scientific disciplines to conceptualize energy. It was clear that different conceptual metaphors and sub-mappings are needed to incorporate all aspects of energy. Therefore, after illustrating isolated expressions of metaphorical expressions found in scientific text, I will refer to Dreyfus, Gupta and Redish's (2015) analysis of a physics professor's lectures to examine whether an expert would blend elements of different conceptual frames when explaining energy. Dreyfus et al. (2015) draw on the conceptual blending framework and on gesture analysis to investigate whether energy as substance metaphor and energy as vertical location metaphor are blended into a single mental space with the concept of energy taking properties from both or are separate mental spaces that are coordinated. The researchers analyzed the gestures that occurred with the speech. For example, pointing to the location on the vertical energy axis of the graph drawn on the board indicates that the person is thinking of *energy as a vertical location*. This analysis provided greater explanatory power. The results demonstrate, through analyzing overlapping speech and gestures, that the two metaphors were joined into a single blended mental space by both the professor and the student. Although analyzing gesture provides more information to understand the meanings the students are making, they will not be examined in this study since it would broaden the scope of the study and the aim is to explore the metaphorical language presented to and used by ELL students.

Metaphorical mapping is used extensively in formal scientific text and discourse to construe the concept of energy. It makes us think of understanding the process of learning the concept of energy in terms of how learners learn to apply and coordinate the metaphors of energy in different contexts. In this regard, Amin (2020) compared the results of two studies that analyzed the use of conceptual metaphors in solving problems on entropy by students of different levels of expertise.

In Jeppsson et al. (2013) an analysis was done on the conceptual metaphors used by PhD students in physical chemistry when solving problems about entropy. In the second study Jeppsson, Haglund and Amin (2015) asked a pair of undergraduate chemistry students to solve the same problems solved by the two PhD physical chemistry students. In both studies the students had to think aloud as they were solving the problems. The PhD students made more productive use of conceptual metaphors. Amin (2020) highlighted the students' metaphorical use of pronouns and coordination of multiple conceptual metaphors to support a highly abstract chain of reasoning. The undergraduates in the study by Jeppsson et al. (2015), on the other hand, used fewer isolated conceptual metaphors that were repetitions of metaphors encountered in textbooks and lectures. Amin (2020) point out that the learning to coordinate multiple appropriate metaphors foster simplified chain of abstract reasoning in problem solving.

Thus, knowing the limitations and strengths of conceptual metaphors and learning how to use them is important for developing scientific expertise.

After illustrating the abundance of metaphorical expressions used in pedagogical discourse and the effectiveness of the coordination of multiple conceptual metaphors in developing expertise in solving problems, Amin (2020) provides more evidence for the importance of conceptual metaphors to conceptual development and its contribution to acquisition of scientific expertise. Amin turns to the findings of a previous study of his, Amin (2009a), to emphasize that a number of metaphorical expressions were found implicit in everyday language use of the concept of energy. A close correspondence between the construal of energy in everyday language and students' naïve conceptions was found and it supports the claim that those languages based construal are additional sources that influence pre-instruction concepts of students as well as the process of conceptual change. Students will draw on those resources as they learn the concept of energy. In addition to this finding Amin (2009a) reported that there was an overlap in the source domains used when conceptualizing energy in lay and scientific setting. This finding highlights the significant degree of continuity in the learning process. The learner has to apply the correct source domain in the right context and learn to apply the right mapping of the source domain.

The set of findings about conceptualizing the energy discussed so far show that metaphorical mapping is extensively used in scientific discourse, everyday language of learners, and shows that there is an overlap in the source domains found in everyday language and students' naïve conceptions and scientific context. There is a need, therefore, to characterize how the learner learns to apply the metaphors they are exposed to in the right context. There is a need to learn how the conceptual metaphor theory can help us understand difficulties that students might encounter when learning to use those metaphors like scientists.

In an attempt to understand how the abstract concept of energy is grasped by the students, we need to examine the use of the metaphors by students in the context of formal instruction in academic settings. The findings of the studies reviewed so far support the fact that substance metaphors form an abundant and fruitful framework in textbooks to help students conceptualize an abstract complex concept such as energy. However, care has to be taken when using those metaphors so that the students do not take them literally.

Brookes and Etkina (2015) demonstrate the importance of language, specifically metaphor representations, in the reasoning about energy. They argue that students are exposed to several metaphors that differ in grammatical structures and this has its consequences on the learning process.

The students in the study had to define heat and three different categories of heat definition were identified: 'caloric/form of energy' definition, 'energy in transit' definition and the 'heat is a transfer of energy' definition. The students then had to answer several questions about an ideal gas, enclosed in a piston and cylinder configuration. To get those answers correct the students had to go beyond state function reasoning with heat. The observations and analysis revealed that the caloric metaphor is connected to reasoning about heat that appears as state function-like reasoning, while those who gave more expert like definitions of heat answered correctly. Students who gave a state function-like reasoning of heat used the caloric metaphor more frequently in their justification compared to students who gave the correct reasoning. In certain situations, however, when no work is done all students gave the correct answer. This showed that the thinking of heat in terms of the substance metaphor was a useful resource in this context. This supports that language is a powerful resource in students' reasoning and the same metaphor that can support the learning process in one context can hinder it in another.

Amin (2020) suggested guiding points for instructional implications. He starts by suggesting that, as a result of the implicit nature of conceptual metaphors in language, teaching the concept of energy requires exposure to real expert discourse. This should be done through cognitive apprenticeship where the teachers' thoughts are heard out loud accompanied by teachers scaffolding the learners thinking and language across a range of reasoning contexts. Therefore, there should be a systematic survey of different contexts where conceptual metaphors are used to construe the concept of energy. This analysis would be translated into the design of effective learning environments.

Amin next highlights the importance of analyzing students' language in classrooms and while solving scientific problems. This analysis was shown to reveal the image-schemas available to students. As mentioned previously Lancor (2014b, 2015) uncovered the conceptual metaphors used by university students to describe the role of energy in different scientific situations. This uncovered the resources students are drawing from. Teachers are then informed if the students are using the right resources and what problems they are facing. Revealing more details of the challenges of mappings between the source domain and target domain helps reach effective instruction design.

Few studies, however, were found to look systematically into the metaphors students are being directly exposed to in science classrooms. The only study found to explore the awareness of students of this metaphorical language and whether they understand it and use it correctly was the study of Wernecke, Schwanewedel, and Harms (2017). This study looked into energy related metaphors and their use in the context of teaching about ecosystems. The aim of the study was to see if the metaphors are adopted and used in the intended way by students in Germany (where instruction is in the native language of the students). It was concluded that they are not.

The focus of the study was on metaphors used in energy transfer in an ecosystem. The four metaphors examined were: energy flow, energy flow is not a cycle, energy flow is a one-way street and energy loss. The questions addressed in the study were:

1. Which features (source domain, highlighted, and hidden aspects) do these metaphors have and how are the metaphors related to each other?
2. How are these metaphors used in teaching material (specifically biology textbooks)?
3. How are these metaphors used in students' descriptions of energy transfer in an ecosystem?

The study was done in three steps. First a survey of metaphor features was done. Next a survey of textbooks' use of metaphors was performed. The last step was a survey of learners' adoption of metaphors. The books surveyed were ten German biology textbooks for lower and upper secondary school from four publishers that are widely approved by German federal states and two English textbooks: Campbell Biology and Biology IB Diploma. The written texts of 50 students from the ninth grade of secondary schools ("Gymnasium") in the German federal state of Schleswig-Holstein were analyzed. A short-standardized presentation about energy transfer in an ecosystem was given to students before the collection of data. Students were given copies of the presentation to view and then they had to write down a description of a diagram that showed energy flow through a forest ecosystem. The students had to “Explain the energy flow through the forest ecosystem on the basis of the diagram. Mention typical characteristics of energy flow, which can be derived from the diagram, and which also apply to energy flows of other ecosystems.” (Wernecke et al., 2017, p.183).

The authors concluded by comparing the textbook use of metaphors with that of students. The energy flow metaphor was used abundantly in textbooks and by students. The students were found to over generalize the energy is a substance metaphor. For example, one of the students even treated energy flow as a substance that can be given up by saying, “the mouse gives 1% of the energy flow through food to the owl.” (p. 187). This could be a result of their experience with things that can flow have usually substance-like properties. One explanation given to why students were not able to apply the Energy Flow is not a Cycle, is that they do not understand what a cycle is. The authors suggest that this metaphor be taught along with the conservation of energy so that students can see how energy could still exist even after it has left the ecosystem. Students might not have used the metaphor Energy Flow is a One-way Street since they did not understand its meaning, although it was used in the presentation given to them. The Energy Lost metaphors’ use seemed to support alternative conceptions. The students did show correct scientific understanding of the energy lost and energy conservation concepts. Those findings imply that more attention should be paid to the use of this metaphors in textbooks and in the classroom.

The previous studies reviewed revealed the aspects of energy and the metaphorical language used in the teaching of energy concepts across the different scientific disciplines and lines of expertise. The metaphorical expressions used in scientific text are sets of conceptual metaphors that are sub-mappings of the substance, process and location event structure metaphors. One metaphor alone is not enough to conceptualize all aspects of the concept of energy (Amin, 2020; Lancor, 2014a, 2014b). Different sets of metaphorical expressions are used systematically to construe different aspects of energy. The success in reasoning about energy and entropy in different contexts requires coordination of different metaphors coherently and in simplified interpretations of the problems at hand (Amin, 2020). Some of the students' naïve conceptions about energy are linked to the language they are exposed to and the resources they draw from. The findings of Wernecke et al. (2017), that showed that students did not adopt and use the metaphors presented in their native language in the intended way, will lead us to ask what would the case be then in an ELL environment?

Language, Concept Learning and English Language Learners

As was discussed previously, communicating, reading, writing, and making-sense of scientific concepts is often challenging to all learners. English Language Learners who are still in the process of acquiring English have an additional challenge of learning the language of science along with its vocabulary and content at the same time as they are developing their English proficiency. In this section, we will take a closer look at the challenges ELLs face when learning science and the strategies that are recommended to target those challenges. Then we will examine the challenges faced by ELLs when exposed to specific linguistic features of sciences discourse such as metaphorical expressions in order to pave the path for our investigation of ELL's awareness, reception, and use of metaphorical language when learning about energy.

Language of Science and English Language Learners

Immigration and the impact of globalization have affected the diversity of students in schools worldwide. It became unavoidable to have students receiving instructions in school in a foreign language. To add to this diversity there exists a popular trend in the Arab world of the use of a foreign language of instruction in schools (Amin, 2009b). Non-native speakers often lag behind native speakers with respect to achievement in science and this is attributed to cultural and linguistic factors (Lee, Deaktor, Hart, Cuevas, & Enders, 2005). A big part of research in science education has focused on exploring challenges and interventions in science education for English Language Learners (ELL) (Lee, 2005; Rollnick, 2000).

In the previous section on language of science and formal science learning, I presented a review of research on the challenging features of science learning and research that addressed students' difficulties learning the language of science. Science language was described as a language that comes with its unique challenging features and formal scientific language that students are not familiar with in their everyday discourse. To add to those challenges and difficulties, ELLs are also expected to learn new concepts in a medium of a second language.

To look into the strategies and instruction that cater to the needs of ELLs when learning science, challenges and situations that hinder conceptual development should be addressed first. Rollnick's (2000) reviewed literature that revealed that the vocabulary, sentence structure and style of language presented in science textbooks makes text inaccessible to ELLs. Rollnick reported that when examining and analyzing teacher talk, it was found that due to the complexity of clauses and use of non-familiar words, science was considered as one of the most linguistically demanding subjects for ELLs. The difficulties in terms of vocabulary, sentence structure and style of science texts were additional challenges to all students especially if their language proficiency was not high. Lee (2005) also reviewed research on science education with ELLs, and considered studies that dealt with linguistic influences on the science learning of ELLs. The review emphasized that high levels of English language proficiency enhanced students' ability to learn scientific content knowledge formulated in English.

Different approaches to science instruction dealing with ELLs were proposed by many researchers to enhance the learning of scientific content. Inquiry based learning is a form of instruction that engages students in investigations of real-life phenomena. Students engaged in such investigation practices learn to implement skills carried out by scientists. At the same time this approach reduces linguistic demands on students when engaged in science learning activities (Buxton & Lee, 2014). In the attempt of reducing the linguistic demand of the new languages introduced, we should not forget the linguistic resources the students bring to class and their effect on the learning process.

The ELL students, that are challenged with formal scientific language and a foreign language of instruction, have already formed a body of pre-existing knowledge of the scientific concept in their native language. Does this pre-exiting knowledge affect the students' conceptualization of energy in English? No study was found to assess how Arab students learn the concept of energy in English; however, one study by Hicham Lahlou (2020) aimed to broaden the understanding of students' misconception of the concept of energy by comparing the prototypes and polysemy of the English energy and Arabic energy (Taqaa). Although the study did not explore ELL's conceptualization of energy; it compared the meanings and categories of energy in both the English and Arabic languages.

The terms on energy were analyzed in English and Arabic dictionaries and corpora that included newspapers, modern literature, non-fiction, spoken text, academic text, and so on. The meanings of the energy in both languages were compared, in addition to the most frequent collocates of the terms. To interpret the polysemy of English energy and Arabic energy (Taqaa), Lakoff's (1987) idealized cognitive models (ICMs) were utilized. An ICM represents how human see and understand a concept. For example, Tuesday is understood as part of a model of a week. This analysis helped establish the prototypes that motivated the conceptualization of energy in both Arabic and English learners. It was found that in both languages the ICM of Energy included 'ability' and 'usable power, a source of power' linked with elements such as action, physical strength, mental strength and electricity and powering machines. However, in Arabic the term energy had denotations like 'window', 'a bunch of', and 'production capacity' which were not found in the English language. Yet those peripheral senses were found to be rarely used in Modern Arabic. It was reported that the collocate frequently used with energy in English was 'efficient'. This evoked features such as energy resources, economy, and sustainability. A less frequent collocate of English energy was 'atomic' which was the most frequent collocate for Arabic energy. This indicates that Arabic energy is frequently associated with forms of energy and with weapons.

Lahlou proposed that English and Arabic learners (each in their native language) of energy would face similar difficulties in learning energy. In both cases, understanding energy maybe motivated by Properties are Contents and Abilities are Entities inside a Person. The meanings intended by the scientific cognitive models to clarify the concepts may not be the same as the existing knowledge in the students' minds. The challenge that faces the teachers, Lahlou presumes, is to help students apply the right cognitive model in the relevant context.

Other studies proposed strategies such as developing and using models to engage ELLs in Language intensive science. Lee, Quinn and Valdés (2013) propose that when ELLs are engaged in language intensive science and engineering practices, both language learning and science learning are promoted. One of the analytical tasks, in such practices, they present is developing and using models. They also include a summary of receptive, productive, and language functions to present scientific sense-making and language use in these tasks and demonstrate how ‘language serves as a vehicle to perform analytical tasks and construct scientific knowledge’ (p.230). Students’ and teachers’ use of language is also summarized. The article presents key features of the language of science classroom that are part of sense-making of scientific concepts and how those features provide a language rich context to support ELLs in learning the language of science and at the same time improving their language proficiency. Although the authors did not report metaphorical expressions as an example of the language features of the analytical tasks, in such practices, they reported developing and using models. How beneficial is the exposure of ELLs to this kind of language register? We have seen in the previous studies the challenges to science teaching that arise from the use of conceptual metaphors where the participants were mostly native speakers of the language of instruction (e. g. Wernecke et al., 2017). This urges us to look at studies that have addressed difficulties that ELLs have with learning to use metaphors in a foreign language, even if this is not specifically in a science context.

Metaphors and English Language Learners

When tackling the issue of learning science in a foreign language considerations of language aspects in social contexts should be taken in to account, in addition to students being participants in social practices of science (Lee, 2005). No study, however, was found to explore English language learners' experiences and challenges faced when exposed specifically to metaphorical expressions in the context of scientific discourse. As reported previously, there is an excessive use of metaphorical language in academic textbooks as well as in students' everyday discourse, especially when it comes to an abstract concept such as energy. How successful is this use of conceptual metaphors when teaching science in an ELL classroom? What challenges might ELLs face in making sense of these conceptual metaphors expressed in a foreign language?

There is a research literature on the challenges of teaching metaphorical language to English language learners in English literacy instruction. Dong (2004) presented a review of challenges of teaching metaphorical language to ELLs in English classrooms. She argues that unlike first language learners, ELLs do not have the cultural and linguistic competence in metaphorical language. ELLs have no cultural reference and have not been immersed in oral discussions using English. They are only prepared for surface features of English and cannot meet challenging language and literacy demands. Without acquiring knowledge about the history and the culture, in addition to, abstract meanings of words ELLs will always be language outsiders. Teachers in English classrooms find that the limited experience ELLs have in metaphorical language affects their reading and writing performance and makes them feel inferior about their language skills. Implementing different strategies is essential to provide students with opportunities and sources to gain this metaphorical language.

Dong suggested that certain strategies could be used to help students acquire the English metaphorical language. In one attempt described by Dong students were asked to draw pictures of the evolution of metaphors they come across in their class readings. It was found that this helped all students not only ELLs. Dong also pointed out the importance of allowing students to look at metaphor in specific contexts and note their meanings. Students' generated reports could serve as a resource for the teachers in helping other students with comprehension in similar contexts. This could serve as a motivation for this study in the context of learning the concept of energy in science. Identifying the image-schemas students use when talking about energy and the mappings they do will aid in teaching this concept.

Students who are not familiar with the meaning of specific scientific metaphors, or who comes from a culturally and linguistically different background and are not aware of the significance of the English metaphor they encounter in science classroom will face difficulties in the learning process. In this study, I aim to look specifically into how Arab ELLs appropriate the metaphors they encounter when learning about energy in biology through academic language that is rich with metaphorical phrases.

Summary

Children start interacting with the physical world and constructing knowledge about the world, long before they start formal schooling. Learners carry this intuitive knowledge they constructed with them to the classroom. Those conceptions are most of the time different from scientific concepts and are targeted by instruction in order to develop the scientifically accepted understanding (Amin, Smith, & Wiser, 2014; Carey, 1986; diSessa, 1998; Vosniadou, & Brewer, 1992; Posner, Strike, Hewson, & Gertzog

1982). Energy is one of the particularly important abstract scientific concepts taught across an extended period in most curricula and across different scientific disciplines (AAAS, 2011; CRDP, 2020; National Research Council, 2012).

The literature review presented earlier surveyed the range of scientific and lay discourse used to conceptualize the concept of energy (Amin, 2020). Excessive conceptual metaphor use was reported in textbooks, scientists' reasoning, and students' conceptions and explanations. Evidence supporting the need for successful coordination of different metaphors is required to reach expertise in this domain, since different metaphors highlight and obscure different aspects of energy. It was found that implicit metaphors in everyday language could be the source of students' misconceptions. An overlap in the source domains learners used to construe energy was found between scientific and lay discourse and all this implies that there is a need for learners to learn to apply the right metaphorical construal in the right contexts to develop a more scientific understanding of energy.

Given the challenges all students face when learning the language of science (Wellington & Osborne, 2001) in general and when exposed to metaphorical expressions (Brookes & Etkina, 2015; Lancor, 2015; Wernecke et al., 2017), a systematic analysis of the range of reasoning context that involves the teaching and learning of energy is recommended (Amin, 2020). The study specifically examined the range of energy metaphors to which ELL Lebanese middle school students are exposed, their use of these metaphors and their interpretation of them in the context of learning about energy in ecosystems. This systematic analysis of the language students are exposed to and language they use revealed the image schematic resources they draw from and whether they are using those resources in a productive way.

CHAPTER 3

METHODOLOGY

Research Design and Overview

This study is a qualitative study of an intact ELL classroom of seventh grade students in Lebanon, that investigated the metaphorical language to which the students were exposed in the context of learning about energy and the metaphors they use when writing about energy in ecosystems. A sample of fifteen students in grade seven participated in the study. The sources of data are the science textbooks through which students have been exposed to the concept of energy, students' writing generated in response to an open-ended writing prompt, and one-on-one interviews. The textbooks the students were exposed to in the previous years and the one they are currently studying from were analyzed to identify energy metaphors in the language of science to which they have been exposed. Students were given a writing prompt where they were asked to explain what happens to energy in an ecosystem. Students' writings were then collected and analyzed and a comparison of metaphor usage in textbooks and students' texts from a conceptual metaphors perspective performed. Finally, students' interpretation of metaphorical language used was explored through interviews. All the students participating in the study participated in one-on-one interviews for a more in-depth examination of their understanding of these energy metaphors.

Population and Sampling

The aim of the study was to investigate how English Language Learners learning science in English interpret and use the energy metaphors they are exposed to in textbooks. The population from which the sample was taken is Lebanese intermediate school students in private schools where English is the foreign language of instruction.

All the students, in the school from which the sample was taken, are English language learners enrolled in a school that teaches all scientific subjects in English since the beginning of elementary school. Lebanese students who have been studying in Lebanon are accepted into the Lebanese Program. Lebanese students who have been studying abroad for the last three years (from the time they apply) and students of other nationalities are accepted into the High School Program. Students of both programs are not separated into different sections according to the two programs until 9th grade, and they attend all subjects together except for Arabic classes. Throughout elementary and intermediate school, the Lebanese Program students study Arabic guided by the official Lebanese curriculum. The fluency in English language varies among the students.

Qualitative research studies focus on a phenomenon we know of but are not very knowledgeable about (Gall, Gall, & Borg, 2010). The phenomenon in this study is English language learners' understanding and use of metaphorical language referring to energy in an ecosystem. For the determination of the participants, seventh grade students in a K-12 secular, non-profit, independent international school in Beirut were invited to participate in the study. Fifteen students out of 23 students volunteered to participate in the study. The fifteen students participated in one-on-one interviews after answering a writing prompt. (this will be elaborated on in details in the interview section of data sources).

Data Sources

Textbook Material

This study seeks to describe the energy metaphors that ELL middle school Lebanese students have been exposed to. Therefore, all the units in science textbooks dealing with energy taught in the elementary years and up to grade 7 were analyzed.

The science textbooks series used in the school is Science Fusion series by Dispezio, Frank, Heithaus, & Ogle (2012). Specific lessons in the 4^{th}, 5^{th}, and 7^{th} grade textbooks, where the concept of energy was targeted, were analyzed. The *Science Fusion Workbook 4* is used in grade 4 and the concept of energy is targeted in Lesson 1: 'What are some forms of energy?' (pp.429-440) and Lesson 3: 'What is Heat?' of unit 9: Energy (pp. 447-453). Grade five textbook is *Science Fusion Workbook 5* and the unit dealing with energy is unit 6: Energy and Ecosystems (pp. 289-313). The biology textbook, *Science Fusion: Ecology and the Environment*, is used in grade seven. The lessons selected for analysis from seventh grade textbook are Lesson 2: 'Roles of Energy Transfer' of unit 1: Interaction of Living Things (pp. 18-27), and Lesson 3: 'Energy and Matter in Ecosystems' of unit 2: Earth's Biomes and Ecosystems (pp. 88-97). The textbooks were examined to analyze how the energy metaphors are used in the instructional material to which the student participants in this study are exposed.

Student Writing about Energy in Ecosystems

At the beginning of the third term of the academic year a pilot study was conducted first to evaluate the quality of instructions in the writing prompt. To check for the clarity of the prompt, the prompt was shared with four students from another section, that were not included in the main study, to answer. The initial writing prompt required the students to write at least 400-500 words (at least 2 pages of A4 paper, double space). To make sure they include as much information as possible about all characteristics of energy they were given a list of key words that they have to mention in their writing. The key words were: sun, producers, consumers, decomposers, environment, chemical, food chain, and food web. They had 45 minutes to respond to the prompt during an online session with their biology teacher. The result showed that asking the students to write up to 400 to 500 words was too much for their level. The presence of a key word list distracted the students' attention away from energy and made them try to write sentences that primarily included the key words instead. In light of this result the prompt was modified to read

> 'An ecosystem consists of a number of living and nonliving components. The living and nonliving components in different ecosystems relate to each other in a variety of different ways. For example, animals eat plants and animals, plants need sun, water, soil and air to grow. Pick an ecosystem of your choice and explain in as much detail as you can where one can find energy in this ecosystem and what happens to energy in this ecosystem.'

The number of words required from the students was reduced to 200 to 300 words.

In the session dedicated for the study the students were given the prompt in which they were asked to explain what happens to energy in an ecosystem as a type of formative assessment to assess their understanding of the objectives targeted up till that date. The students were informed that one session will be dedicated for them to write about what happens to energy in an ecosystem. Students' texts were analyzed and a comparison of metaphor usage in textbooks and student's texts was done.

Interviews

The conducted interviews were based on the students' answers to the open-ended writing prompt of the study. The fifteen participants in the study participated in the follow up interviews.

The interview guideline allowed students to provide continuing thoughts explaining their use of metaphors and this allowed the interviewer to ask follow-up questions about the statements they are using. The probes following their answers addressed their awareness of the metaphorical language and its purpose, or what did they understand it to mean. The interviews were audiotaped and transcribed verbatim for later analysis. If students were found to struggle in their explanation, they were encouraged to use Arabic. The Arabic statements, if present, were analyzed for metaphorical meanings just like the written English.

To see what the students meant by each metaphor, all sentences that include the word ‘energy’ were picked from what they wrote and they were asked to explain it in more detail. The students were asked questions that revealed whether they understand that this is a metaphor. They were asked questions that explored their awareness of the metaphorical nature of the statement they wrote. For example, an answer such as “Energy flows from producers to consumers.” was followed by a more explicit question such as ‘You said in your answer ‘Energy flows from producer to consumer’ can you explain what you mean by that?’. To get the student to elaborate the question was followed by ‘What do you mean by energy flow?’ The next question examined the student’s awareness of the metaphorical language. The next question was ‘The word ‘flow’ means something is moving from one place to another, do you really believe that something is actually flowing from producer to consumer?’ The student was then given a metaphorical expression used in everyday language where the word ‘flow’ is treated as metaphorical followed by a question to explore whether they are aware that this is a metaphor. The question was ‘People say ‘When I sit by the sea to write, the flow of ideas becomes smoother’ do they really mean that ideas are flowing into the writer’s head as he writes?’ Then they were asked to explain whether this use of language is similar or different from the phrase they wrote about energy. The question was ‘How is this similar to or different from saying ‘energy flows from producer to consumer?’ The same form of questions was asked about each metaphorical expression including energy in the student's writing.

Data Collection Procedure

The school principal was contacted for permission to conduct the study at the school and allow the researcher to approach a seventh-grade class to invite them to participate in the study. Once the permissions from the principal and class teacher were granted, the parents were contacted to get their consent regarding student participation; the students were also asked to provide their consent.

First to analyze the metaphors presented in the textbooks, chapters dealing with energy were chosen as described above. In addition to the main text, the information on the selected pages to be analyzed, included headlines, pictures with their labels and captions. An example of a page rich with text containing energy expressions from the 7^{th} grade textbook is included in Appendix A.

As planned the study was conducted in the third term of the school year. The students of grade seven in the school had all their classes conducted online during the whole year due to the pandemic situation. The biology teacher shared the prompt with the students online, asked them to switch on their cameras (as they usually do), and told them they had 45 minutes to answer the prompt. Students shared their answers with the teacher in a folder created on Google Classroom. (Samples of the writings of three students are presented in Appendix B). Students' texts were analyzed and a comparison of metaphor usage in textbooks and student's texts was done.

Individual interviews were conducted with the 15 students as described above after the analysis of the students' writings has been completed. Each interview was about thirty minutes long to make sure the students were given enough time to elaborate on what they wrote. The interviews were audiotaped and transcribed verbatim for later analysis (A sample of a student's transcribed interview is presented in Appendix C).

Data analysis

The identification and use of the metaphors in the textbooks and the texts of the students were analyzed systematically in three phases described below.

Phase One

The first phase was to identify the instances of explicit and implicit energy metaphors presented in the specified pages of the textbooks. Explicit and implicit metaphors used in the textbooks were identified drawing on the methodology used in the study by Amin et al. (2012). Literature on energy instruction identified five aspects of energy: energy conservation, energy degradation, energy transformation, energy transfer, and energy source (Lancor, 2014b; Lee, & Liu, 2010; Nordine, Krajcik, & Fortus, 2010). Metaphorical expressions used to describe energy were examined. Explicit metaphors identified were those indicated by quotation marks, italics, and lexical markers such as *as, like, can be thought of as, similar to, can be seen as*.

As for the implicit metaphors the Metaphor Identification Procedure (MIP) developed by the Pragglejaz Group (2007) was used. This procedure is applied to any sentence to identify any metaphorical lexical unit found in it. Any sentence suspected of having any metaphorical meaning when addressing any characteristic of energy was selected for an in-depth analysis. The procedure for identifying a metaphorical expression was done in two steps. First the lexical unit was interpreted for its contextual meaning as it is meant in the context of the sentence. Next, we searched to see if the lexical unit has a "more basic contemporary meaning in other contexts than the one in the given context" (Pragglejaz Group, 2007, p. 3); by more basic we mean a more concrete meaning. The final step was to decide, “whether the contextual meaning contrasts with the basic meaning but can be understood in comparison with it” (p. 3). In this case the sentence was interpreted as metaphorical. Consider the following example:

> “Arrows in the web point in the direction that energy moves.” (*Science Fusion Workbook 5*, p.310)
> Candidate metaphorical lexical unit: “energy moves”
> Contextual meaning:
>
> a. Of whole sentence: Energy increases in one part of the system (where the arrow is coming from) and decreases in another (where the arrow is point to).
> b. Of candidate metaphorical lexical units: “energy moves”: energy is transferred
>
> Basic meaning:” Move” is an action verb that refers to an object changing position or place and going to a different place. Thus, it has a more concrete spatial meaning than the contextual meaning. Since an object changing place is like being transferred by an agent from one location to another, then “energy moves” is treated as metaphorical where energy is given the characteristic of a substance being transferred from one location to another.

All the metaphors identified in the textbook were included even if they appeared without discussion or elaboration.

Phase Two

The metaphors identified in the textbooks were then grouped together based on a method of constant comparison which draws on the methodology used by Lakoff and Johnson (1980) who identified metaphorical phrases in language and grouped them together by theme. Conceptual metaphors and their sub mappings previously identified in texts dealing with energy and energy transfer (Amin, 2009a) served as an initial coding scheme for the categorization of metaphorical expressions. The metaphorical expressions were organized in term of Object Event Structure metaphor and Location Event Structure metaphor.

For coding the metaphors for the aspects of energy we draw on the coding procedure followed by Amin (2009a). Metaphors were examined to see what aspects of energy they highlight. The criteria for each aspect as presented by Amin (2009a) are:

- Energy conservation. Metaphors that showed evidence of energy conservation are the ones that discussed a fixed amount of energy, or inferred that energy is never lost, destroyed, or created. E.g. *Energy cannot be created or destroyed*
- Energy degradation. Evidence of energy degradation should point out that energy can be lost or that the total amount of useable energy in a system decreases. E.g. *Energy is lost to the environment*
- Energy transformations. Evidence of transformation presented energy as having the ability to change forms. E.g. *Energy changes forms*
- Energy transfer. Evidence of energy transfer shows that energy move from one place to another or is moved via an agent. E.g. *Energy is transferred from organism to organism*

Phase Three

The same procedure followed in phase one in determining the implicit metaphors used in the textbooks was followed to identify the metaphors used in the students' texts. Next the same categorization process, as in phase two, was used to group the metaphors into conceptual metaphors. The students' writings were analyzed to see how far the students' descriptions of energy and metaphors reflected the use of metaphors in the textbooks.

Phase Four

The verbatim transcriptions of the interviews were examined inductively to answer questions that revealed the students' awareness of metaphors used and how they interpret the metaphors. Statements, including the word 'energy', from what students have written were selected and students were asked questions that helped them elaborate more on what they meant by those specific statements. Allowing students to elaborate on key phrases used metaphorically was intended to unpack the mapping. When students explain what the sentence means to them one can infer some ideas of how they are doing the mapping and how source domains are getting used in their thinking. Further questions that revealed their understanding of metaphorical language used in everyday discourse clarified the students' awareness of this type of language. Then, students were asked to compare the statements they wrote to describe energy with the metaphorical statements used in everyday discourse.

The next step was to break the interview text into segments, define specific categories that reflect important conceptual elements in the text, and finally code each segment into the categories defined previously. The coding was done through a process of open-coding using a constant comparative method. The coding categories that emerged captured the nature of students' understanding of energy as reflected in their explanations (A sample of the coding of segments from the students' interviews is presented in Appendix D).

Reliability

With regard to metaphor identification, the Pragglejaz Group acknowledges some degree of subjectivity, but the MIP procedure has been developed to allow for a more systematic discussion for the basis of metaphor identification. With regard to categorizing the metaphors identified within conceptual metaphor construal categories, two coders analyzed the place of metaphorical expressions within categories. The expressions identified by the first researcher in the textbooks and students' writings as including metaphorical lexical units were shared with another coder who also categorized the expressions into metaphorical construal categories. The coders met and discussed any disagreements in categorization which were resolved through discussion.

CHAPTER 4

RESULTS

The findings of the study are organized in this chapter into three sections. In the first section, all the metaphors identified in the units in science textbooks dealing with energy taught from the elementary years up to grade seven are presented and categorized into distinct metaphorical construal types. In the second section, the analysis of the students' writings to identify the metaphors they used to construe energy is presented along with the analysis of how far the metaphors they used to construe energy resembled the use of metaphors in the textbooks. Finally, in the last section, an interpretational analysis of students' interviews is reported that revealed whether the students were aware of their usage *as* metaphorical and how they interpret these metaphors.

Analysis of Textbooks

The objective of this first analysis was to identify the metaphorical expressions used in the textbooks to explain the concept of energy that students are exposed to throughout elementary school up to grade seven. All expressions in the units that contain the word energy were analyzed from the perspective of conceptual metaphor theory. As described in Chapter 3, explicit metaphors should be indicated by quotation marks, italics, and lexical markers such as *as, like, can be thought of as, similar to, can be seen as*. However, no explicit metaphors describing energy were identified in any of the units dealing with energy in the textbooks.

As for the implicit metaphors, the Metaphor Identification Procedure (MIP) was applied. After identifying the metaphorical lexical item found in expressions containing the word energy using MIP, the metaphorical expressions were categorized in terms of the aspect of energy they conceptualize. The metaphorical expressions were then grouped into categories of conceptual metaphors according to the sub mappings they reflect. A total of 13 expressions out of 120 expressions used in the three textbooks were not classified as metaphorical. Expressions that defined energy as the ability to do work, expressions that described the need of organisms or things for energy, and expressions that stated the law of conservation of energy did not employ any metaphorical meaning.

After identifying the metaphorical lexical items found in the expressions picked from the units in the textbooks, the metaphors were organized in terms of the four aspects of energy: transfer, transformation, conservation and degradation. Conceptual metaphors and their sub mappings previously identified in texts dealing with energy (Amin, 2009a; Amin et al., 2012) served as an initial coding scheme for the categorization of metaphorical expressions.

The Object Event Structure metaphor and the Location Event Structure metaphor (as applied to energy) with their sub mappings (Lakoff & Johnson, 1999) were used as an initial coding scheme for the categorization of metaphorical expressions. The sub-mappings of the Object Event Structure metaphor used were: Energetic State is a Possession, Change in Energetic State Is Movement of a Possession, Caused Change in Energetic State Is Transfer of a Possession and elaborations in terms of containment. The Location Event Structure metaphor sub mappings used were: Forms of Energy Are Locations, Changes in Forms of Energy Are Movements into (out of) Containers, and elaborations in terms of resource schema, and force dynamic schema.

The metaphorical expressions reflecting energy transfer were found to be organized in terms of the Object Event Structure metaphor and an elaboration of it in terms of containment. The sub-mappings of the Object Event Structure metaphor employed were reflected in expressions such as ‘So everything that moves *has* energy’ (*Science Fusion Workbook 4,* p. 431) which reflects Energetic State Is a Possessions, ‘Heat is the energy that *moves between* objects of different temperatures’ (*Science Fusion Workbook 4*, p. 448) which reflects Change in Energetic State Is Movement of a Possession, and ‘The difference in temperature *makes the energy move*’ (*Science Fusion Workbook 4*, p. 448) which illustrates Caused Change in Energetic State Is Transfer of a Possession where a forced change causes the energy to change place. The elaboration in terms of containment is revealed in expressions that refer to possessors of energy having energy *in* a container (Energetic State Is Content of a Container) e.g. ‘Consumers use the energy and nutrients *stored in* other living organisms because they cannot make their own food.’ (*Science Fusion: Ecology and the Environment,* p.21) or in expressions where energy *enters* or *leaves* it (Change of Energetic State Is Movement into (or out of) a Container) e.g. ‘Ecosystems do not have clear boundaries, so energy and matter can *leave* them.’ (*Science Fusion: Ecology and the Environment,* p.91).

All the metaphors that reflected energy transformation were organized in terms of the Location Event Structure metaphor. The sub mappings of the Location Event Structure metaphor employed were reflected in expressions such as ‘Electric energy is energy that *comes* from electric current.’ (*Science Fusion Workbook 4,* p. 434) which illustrates Forms of Energy Are Locations/Containers, and ‘Through photosynthesis, producers *convert* this light energy *into* chemical energy in sugars, which they use for food.’ (*Science Fusion Workbook 5,* p. 309) which illustrates Changes of Form of

Energy Is Movement into (out of) Containers. Another metaphor used to further understand energy in some form is Energy in Some Form Is a Resource. For example, 'Electric energy *provides the energy* for most of the devices you use, like computers and televisions.' (*Science Fusion Workbook 4*, p. 437) reflects this metaphor. When energy is conceptualized as a resource and some restraint is removed to let go of this energy the Force Dynamic Elaboration of the resource schema is used as in 'During respiration, sugars are broken down *to release energy*.' (*Science Fusion: Ecology and the Environment*, p.96)

The aspect of energy conservation that shows how energy is conserved in all interactions taking place is understood through many conceptual metaphors. In order to understand this aspect of energy, energy is quantified and those quantities add up to a conserved total quantity. The metaphor Energy as Amount of Substance was the only conceptual metaphor reflected in all three textbooks in different expressions such as '*limited amount* of energy available to them.' (*Science Fusion: Ecology and the Environment,* p.92) and 'Third consumers like …, have the *least amount* of energy available to them.' (*Science Fusion Workbook 5,* p. 312).

The last aspect of energy, degradation, that refers to the decrease in the usefulness of energy through interactions in a system, was illustrated in three expressions in 7th grade textbook. One expression mentioned loss of energy without specifying that energy is lost as heat, 'At each step in the food chain, energy is lost to the environment' (*Science Fusion: Ecology and the Environment*, p.92). The other two expressions referred to loss of energy as heat such as 'However, some energy is lost to the environment as heat.' (*Science Fusion: Ecology and the Environment*, p.92). All three expressions reflect the conceptual metaphor Change of Energetic State of System Is Loss of Energy from System.

A summary of the frequencies of all the conceptual metaphors reflected by the energy expressions identified in the three textbooks is presented in Table 1 below. The proportions of each conceptual metaphor describing the different aspects of energy in relation to the total number of the expressions of that aspect in each textbook are also presented.

The metaphorical expressions in the textbooks were categorized according to the aspect of energy they addressed and in terms of the conceptual metaphor they reflect, discussed above. Examples of illustrations of the conceptual metaphors identified in the units of the textbooks, are presented in Tables 2, 3, and 4 as they appear in the three textbooks: *Science Fusion Workbook 4*, *Science Fusion Workbook 5* and *Science Fusion: Ecology and the Environment* respectively.

Table 1

Frequencies (f) of Each Conceptual Metaphor and the Proportions (p) of Each Conceptual Metaphor out of the Total Number of Expressions (EX) Reflecting Each Aspect in Each Textbook (TB) of the Different Grade Levels (G4, G5, G7)

Aspect of energy	Construal type	G4 TB		G5 TB		G7 TB		*p* out of EX in all TB
		f	*p*	*f*	*p*	*f*	*p*	
Transfer	Energetic State Is a Possession	8	0.44	0	0	0	0	0.11
	Change in Energetic State Is Movement of a Possession	8	0.44	10	0.625	17	0.46	0.49
	Caused Change in Energetic State Is Transfer of a Possession	2	0.11	6	0.375	7	0.19	0.21
	Energetic State Is Content of a Container	0	0	0	0	9	0.24	0.13
	Change of Energetic State Is Movement into (or out of) a Container	0	0	0	0	4	0.11	0.06
Transformation	Forms of Energy Are Locations/ Containers	1	0.05	0	0	0	0	0.03
	Changes of Form of Energy Is Movement into (out of) Containers	8	0.42	1	0.33	2	0.17	0.32
	Accessing Stored Energy Is Removal of Restraint	2	0.11	0	0	2	0.17	0.12
	Energy in Some Form Is a Resource	8	0.42	2	0.67	8	0.66	0.53
Conservation	Energy State Is Amount of Substance	2	1	2	1	8	1	1
Degradation	Change of Energetic State of System Is Loss of Energy from System	0	0	0	0	3	1	1

Grade Four Textbook

In the *Science Fusion Workbook 4* used by students in grade 4 two lessons that dealt with energy were selected for analysis. Thirty-nine metaphorical expressions were identified and categorized in terms of the aspects of energy conceptualized and conceptual metaphors they reflect. Table 2 presents examples of expressions found in the 4th grade textbook.

Table 2

Examples of Statements about Energy in Science Fusion Workbook 4

Aspect of energy	Construal type	Examples
Transfer	**-Object Event Structure Metaphor**	
	Energetic State Is a Possession	'So everything that moves *has* energy.' (p. 431)
	Change in Energetic State Is Movement of a Possession	'Heat is the energy that *moves between* objects of different temperatures.' (p. 448)
	Caused Change in Energetic State Is Transfer of a Possession	'The difference in temperature *makes* the energy *move*.' (p. 448)
Transformation	**-Location Event Structure Metaphor**	
	Forms of Energy Are Locations/Containers	'Electric energy is energy that *comes* from electric current.' (p.434)
	Changes of Form of Energy Is Movement into (out of) Containers	'As the cars go down a hill, their potential energy decrease because it *changes to* kinetic energy.' (p. 433)
	Accessing Stored Energy Is Removal of Restraint	'In most cities, electricity is generated using the chemical energy *released* during

		the burning of fossil fuels such as coal and natural gas.' (p. 437)
	Energy in Some Form Is a Resource	'Electric energy *provides the energy* for most of the devices you use, like computers and televisions.' (p.437)
Conservation	**-Object Event Structure Metaphor**	
	Energy State Is Amount of Substance	'Runners eat healthful foods such as trail mix so they will have *plenty of* energy.' (p. 431)

A total of 18 out of 39 expressions were identified in 4th grade textbook that addressed energy transfer and reflected the metaphorical construal: Energetic State Is a Possession, Change in Energetic State Is Movement of a Possession, and Caused Change in Energetic State Is Transfer of a Possession. The expressions dealing with energy transfer reflected the Object Event Structure metaphor and its sub mappings. The sub mapping Energetic State Is a Possession was reflected in eight expressions out of 18 expressions describing energy transfer and referred to object *having energy*. To conceptualize transfer of energy as movement of possession eight out of the 18 expressions describing energy transfer described energy as *moving* or *gained* and two out of 18 expressions described energy as *given off*. Two out of the 18 expressions describing energy transfer reflected Caused Change in Energetic State Is Transfer of a Possession.

There were 19 expressions out of the 39 expressions identified in the 4th grade textbook that illustrated transformation of energy and reflected the conceptual metaphors Forms of Energy Are Locations/Containers, Changes of Form of Energy Is Movement into (out of) Containers, Accessing Stored Energy Is Removal of Restraint, and Energy in Some Form Is a Resource. Specifically, one expression out of the 19 expressions describing energy transformation only reflected Forms of Energy Are Locations/Containers. Changes of Form of Energy Is Movement into (out of) Containers was reflected in eight out of the 19 expressions and described how energy changes forms *from* one *to* another. Eight out of the 19 expressions were used in the textbook to describe the existence of energy in different forms, all of which reflected Energy in Some Form Is a Resource. Two out of the 19 expressions referred to *energy released* and were identified as reflecting the conceptual metaphor Accessing Stored Energy Is Removal of Restraint.

Two expression out of the total 39 expressions in the 4th grade textbook reflected Energy State Is Amount of Substance e.g. *plenty of energy*. Such expressions mapped conservation of energy on the amount of a substance to keep track of contributions of energy of different parts of a system. Only two expressions addressed conservation of energy in the 4th grade textbook, while no expressions illustrating energy degradation were identified in the 4th grade textbook.

Grade Five Textbook

One unit in the textbook of grade 5, *Science Fusion Workbook 5,* dealt with energy and ecosystems. This unit contained 21 expressions that illustrated energy transfer, transformation and conservation. Table 3 presents examples of the expressions found in the 5th grade textbook.

Table 3

Examples of Statements about Energy in Science Fusion Workbook 5

Aspect of energy	Construal type	Examples

Transfer	**-Object Event Structure Metaphor**	
	Change in Energetic State Is Movement of a Possession	'Arrows in the web point in the direction that energy *moves*.' (p. 310)
	Caused Change in Energetic State Is Transfer of a Possession	'Second-level consumers eat herbivores and *receive* the food energy stored in their body.' (p. 309)
Transformation	**-Location Event Structure Metaphor**	
	Changes of Form of Energy Is Movement into (out of) Containers	'Through photosynthesis, producers *convert* this light energy *into* chemical energy in sugars, which they use for food.' (p. 309)
	Energy in Some Form Is a Resource	'Reindeer moss *uses* energy from the sun to make and store sugars.' (p. 308)
Conservation	**-Object Event Structure Metaphor**	
	Energy State Is Amount of Substance	'Third consumers like …, have the *least amount* of energy available to them.' (p. 312)

Sixteen expressions out of the 21 expressions identified in the 5th grade textbook involved energy transfer and reflected only two sub mappings of the Object Event Structure: Change in Energetic State Is Movement of a Possession and Caused Change in Energetic State Is Transfer of a Possession. The lexical phrases of the metaphors reflecting Change in Energetic State Is Movement of a Possession were *energy moves, passes, flows* and *the transfer of energy*. Most of the expressions that dealt with transfer of energy as a result of a caused force include verbs such as energy *captured, received* and *passed* by organisms. One expression out of the 16 expressions describing energy transfer includes energy *coming from* food to describe caused transfer of energy.

A total of 3 expressions out of 21 addressed energy transformation in the 5th grade textbook. Only one expression out of the three expressions describing energy transformation reflected Changes of Form of Energy Is Movement into (out of) Containers where energy forms are containers and transformation is movement in and out of containers. For example, any expression showing movement of energy *from* one form *into* another such as energy being *converted into* some form reflects this mapping. Energy in Some Form Is a Resource was reflected in two expressions out of the three expressions where energy in some form is considered a resources.

Energy conservation was metaphorically construed in two expressions out of the 21 expressions identified in the 5th grade textbook. The two expressions reflected Energy State Is Amount of Substance where energy was quantified in terms of amount of a substance e.g. *least amount* of energy available. No expressions were found to reflect energy degradation in the 5th grade textbook.

Grade Seven Textbook

In grade 7 textbook, *Science Fusion: Ecology and the Environment,* a total of 60 expressions were identified. The expressions were categorized into expressions reflecting energy transfer, energy transformation, and energy conservation like the expressions in the 4th grade and 5th grade textbooks. However, some expressions in the 7th grade textbook were also identified to reflect energy degradation. Examples of the categorized expressions from the 7th textbook are presented below in Table 4.

Table 4

Examples of Statements about Energy in Science Fusion: Ecology and the Environment

Aspect of energy	Construal type	Examples

Transfer	**-Object Event Structure Metaphor**	
	Change in Energetic State Is Movement of a Possession	"Energy *moves* from one organism to the next in one direction." (p.23)
	Caused Change in Energetic State Is Transfer of a Possession	"In this way, energy is *transferred* from organism to organism." (p.22)
	Energetic State Is Content of a Container.	"Only chemical energy that an organism has *stored* in its tissues is available to consumers." (p.22)
	Change of Energetic State Is Movement into (or out of) a Container	'Even though the matter and energy *enter* and *leave* an ecosystem, they are never destroyed.' (p.91)
Transformation	**-Location Event Structure Metaphor**	
	Changes of Form of Energy Is Movement into (out of) Containers	'Some producers *change* light energy *from* the sun *to* chemical energy in sugars.' (p.91)
	Accessing Stored Energy Is Removal of Restraint	'During respiration, sugars are broken down to *release* energy.' (p.96)
	Energy in Some Form Is a Resource	"In photosynthesis, producers *use* light energy to make food from water, carbon dioxide, and nutrients found in water and soil." (p.20)
Conservation	**-Object Event Structure Metaphor**	
	Energy State is Amount of Substance	'A *small amount* of energy is stored within an organism.' (p.92)

Degradation	**-Object Event Structure Metaphor**	
	Change of Energetic State of System Is Loss of Energy from System	'During every process, some energy *is lost* as heat.' (p.91)

A total of 37 out of 60 metaphorical expressions were identified in the 7th grade textbook to describe transfer of energy. Those expressions reflected the following conceptual metaphors: Change in Energetic State Is Movement of a Possession, Caused Change in Energetic State Is Transfer of a Possession, Energetic State Is Content of a Container, and Change of Energetic State Is Movement into (or out of) a container. Seventeen out of the 37 expressions reflected Change in Energetic State Is Movement of a Possession and included lexical phrases such as *transfer of energy, flow of energy, energy flows* and, most frequently, *energy moves* between organisms. Seven out of the 37 expressions reflected Caused Change in Energetic State Is Transfer of a Possession and explained energy transfer due to a forced change. Two out of those seven expressions referred to energy as being *transferred* as a result of feeding action. The other expression referred to energy being *given* off. Four expressions describe energy as being *taken in* by organisms. Nine out of the 37 expressions describing energy transfer reflected Energetic State Is Content of a Container, where energy is contained *in* something, were identified such as referring to energy is *saved within* the organism. Change of Energetic State Is Movement into (or out of) a container was reflected in four out of the 37 expressions where energy is *leaving* or *entering* a container.

There were 12 out of 60 metaphorical expressions in the 7th grade textbook that dealt with energy transformation. Two out of the 12 expressions reflected Changes of

Form of Energy Is Movement into (out of) Containers. Expressions that include the verb *change* clearly illustrate the transformation of one energy from one form to another e.g. Some producers *change* light energy *from* the sun *to* chemical energy in sugars. Two out of the 12 expressions reflected Accessing Stored Energy Is Removal of Restraint where energy is *released* as a result of a process e.g. sugars are broken down *to release* energy. Energy in Some Form Is a Resource was illustrated in eight out of the 12 expressions describing energy transformation where different forms of energy are *used* or *supplied* e.g. The food that these producers make *supplies* the energy for other living things in an ecosystem. Overall, the 12 expressions reflected: Changes of Form of Energy Is Movement into (out of) Containers, Accessing Stored Energy Is Removal of Restraint, and Energy in Some Form Is a Resource.

Eight out of 60 expressions in the 7th grade textbook illustrated Energy State Is Amount of Substance and referred to *amount, limited amount of energy*, *most*, and *less* energy. Those eight expressions presented described energy conservation.

Grade 7 textbook was the only textbook among the three textbooks analyzed where three out of 60 expressions in the 7th grade textbook address energy degradation. The three expressions reflected Change of Energetic State of System Is Loss of Energy from System which construed change in energetic state as loss of energy as possession (as heat) e.g. 'energy *is lost* as heat' (p.91).

Descriptions of Aspects of Energy in the Textbooks

The conceptual metaphors describing energy transfer that were most frequently reflected in the 4th grade textbook were Energetic State Is a Possession (p=0.44) and Change in Energetic State Is Movement of a Possession (p=0.44). Unlike the 4th grade textbook, the 5th and 7th grade textbook did not include any expressions reflecting

Energetic State Is a Possession. In the textbooks of grade five and seven the expressions describing energy transfer mostly reflected Change in Energetic State Is Movement of a Possession ($p=0.625$ and $p=0.46$ respectively). Energetic State Is Content of a Container and Change of Energetic State Is Movement into (or out of) a Container were only reflected by expressions identified in the 7^{th} grade textbook, where the proportion of those conceptual metaphors out of the expressions describing energy transfer in the 7^{th} grade textbook were $p=0.24$ and $p=0.11$ respectively. The most used conceptual metaphor describing energy transfer among all the expressions describing energy transfer in all three textbooks was Change in Energetic State Is Movement of a Possession ($p=0.49$).

One expression describing energy transformation and reflecting Forms of Energy Are Locations/Containers was only identified in the 4^{th} grade textbook. Most of the expressions in the 4^{th} grade textbook describing energy transformation reflected Changes of Form of Energy Is Movement into (out of) Containers ($p=0.42$) and Energy in Some Form Is a Resource ($p=0.42$). The proportion of expressions reflecting Changes of Form of Energy Is Movement into (out of) Containers out of the expressions describing energy transformation in separate textbooks decreased to $p=0.33$ in the 5^{th} grade textbook and $p=0.17$ in the 7^{th} grade textbook. On the contrary, the proportion of Energy in Some Form Is a Resource increased to $p=0.67$ and $p=0.66$ in the 5^{th} and 7^{th} grade textbooks respectively.

The only conceptual metaphor describing energy conservation in all textbooks was Energy State Is Amount of Substance. Change of Energetic State of System Is Loss of Energy from System was the only conceptual metaphor reflected by expressions describing energy degradation and it was only identified in the 7^{th} grade textbook.

An overall examination of the metaphorical expressions that appear in the textbooks that students of grade 7 are exposed to from the early elementary years until grade seven, allows us to see some changes in the use of energy metaphors to describe the four aspects of energy through the grades. Table 5 below presents the number of expressions categorized in terms of the aspects of energy they reflect. The proportions of the expressions reflecting each aspect of energy identified in each textbook in relation to the total number of energy expressions in that textbook are included. The proportions of expressions reflecting each aspect of energy in all textbook in relation to the total number of energy expressions in all textbooks are also included.

The two units in the 4th grade textbook dealing with energy focused on energy in physical science context and not in biological contexts such as ecosystems. The expressions were distributed into 18 expressions involving energy transfer, 19 expressions involving energy transformation and only two involving energy conservation. The expressions were distributed among the three aspects of energy: transfer, transformation and conservation with a slight increase in number of expressions involving transformation. As a consequence, the proportion of expressions reflecting the Location Event Structure metaphor to make sense of energy transformation was 0.49 and the proportion of expressions reflecting the Object Event Structure metaphor utilized to make sense of energy transfer and conservation was 0.51.

Table 5

The Frequencies (f) of Expressions (EX) Reflecting Different Aspects of Energy and their Proportions (p) in the Textbooks (TB) of Different Grade Levels (G) Analyzed

Aspect of energy	G4		G5		G7		*p* of EX of each aspect out of total number of EX in all TB
	f	*p*	*f*	*p*	*f*	*p*	
Transfer	18	0.46	16	0.76	37	0.62	0.59
Transformation	19	0.49	3	0.14	12	0.20	0.28
Conservation	2	0.05	2	0.1	8	0.13	0.1
Degradation	0	0	0	0	3	0.05	0.03

The unit analyzed in the 5th grade textbook dealt with energy and ecosystems. The metaphorical expressions identified were distributed among the three aspects of energy: transfer, transformation, and conservation. However, the focus was on energy transfer. The largest proportion of energy expressions (p=0.76) was of expressions involving energy transfer. The proportion of expressions describing energy transformation was 0.14, and that of expressions describing energy conservation was 0.1. Therefore, the Object Event Structure metaphor and an elaboration of it in terms of containment were utilized the most to make sense of energy transfer and energy conservation (p=0.86) compared to the use of the Location Event Structure metaphor describing energy transformation (p=0.14).

The two units of 7th grade textbook focused on energy, matter and the role of energy transfer in the context of ecosystems. Sixty metaphorical expressions were identified and categorized with 37 expressions reflecting energy transfer, 12 expressions reflecting energy transformation, eight expressions reflecting energy conservation and three expressions reflecting energy degradation. Although, expressions reflecting energy degradation appeared in the 7th grade textbook, the proportion of those expressions out of the total number of energy expressions in the textbook was still very low (p=0.05). The proportion of expressions reflecting the Object Event Structure metaphor used to describe energy transfer, conservation and degradation remained higher (p=0.8) than the proportion of expressions reflecting the Location Event Structure metaphor (p=0.2) used to describe energy transformation in the 7th grade textbook.

The use of the Object Event Structure metaphor to describe energy transfer and conservation (p=0.51) and the Location Event Structure metaphor to describe energy transformation (p=0.49) were approximately equal in the 4th grade textbook. However, when comparing the use of the Object Event Structure metaphor and the Location Event Structure metaphor between grades four and five, it is noted that there was an increased use of the Object Event Structure metaphor and its elaborations to describe energy transfer and conservation (p=0.86) compared to the use of the Location Event Structure metaphor to describe energy transformation (p=0.14). Although it is also noticed that the number of expressions describing energy conservation increased in 7th grade textbook (f=8) compared to 4th (f=2) and 5th (f=2) grade textbooks, the proportion of those expressions out of the total number of expressions in the textbooks was still very low, where the proportions were 0.05, 0.1, and 0.13 in the 4th, 5th, and 7th grade textbooks respectively. It is also noted that from a broader scale comparison of the use of expressions describing the different aspects of energy, energy transfer is reflected in almost half (p=0.59) of the expressions used throughout the years compared to expressions describing transformation (p=0.28), conservation (p=0.1) and degradation (p=0.03).

Analysis of Students' Writings

Fifteen grade seven students participated in the study. The students were given a prompt to respond to where they were asked to pick an ecosystem of their choice and explain in as much detail as they can where one can find energy in this ecosystem and what happens to energy in this ecosystem. Their texts contained on average 176 words (range 47-315). The total number of metaphorical expressions containing the word energy identified in the students' writing was 63 expressions. The 63 expressions were distributed into 42 expressions describing energy transfer, 16 expressions describing energy transformation, three expressions describing energy conservation and two expressions referring to energy degradation.

All of the sentences the students used to explain what happens to energy in an ecosystem were identified as metaphorical except for the texts written by five students who explicitly referred to energy in their sentences as an object or a thing. Student 2 (S2) said literally that sugar is known as energy (turning it into sugar a.k.a energy). S13 however, referred to the sunlight taken by plants as energy by writing, 'As an example there is a plant known as a producer that is taking sunlight from the sun as energy'. S12 was also explicit about energy being a thing by writing, 'Energy is the thing that lets our body move physically and chemically.' The rest of the phrases written by the students illustrated metaphorical expressions (according to the analysis revealed by applying MIP even if the interviews showed otherwise, as will be presented later).

The same procedure of analysis was applied to identify the metaphorical expressions in the students' writing and categorize them in terms of the conceptual metaphors they reflect and the energy aspects they conceptualize. Examples of statements written by students are presented in Table 6 that follows.

Table 6

Examples of Statements about Energy in Students' Writings

Aspect of energy	Construal type	Examples
	Not metaphorical	'turning it into sugar a.k.a energy' (S2)
Transfer	**-Object Event Structure Metaphor**	
	Energetic State Is a Possession	'When the rabbits are extinct the foxes will also be extinct because they don't *have* any energy to take, you see where this is going, the decomposers won't

		have any energy and then they will die.' (S15)
	Change in Energetic State Is Movement of a Possession	'Plants *get* energy from the sun' (S2)
	Caused Change in Energetic State Is Transfer of a Possession	'Now 10% of that energy *is passed* on to the animals that ate the grass' (S14)
	Energetic State Is Content of a Container.	'Energy *in* an ecosystem is produced by the process of photosynthesis' (S12)
	Change of Energetic State Is Movement into (or out of) a Container	'then when all these organisms die the job is for the decomposers which are the fungi to decompose the organisms and *put* all that energy back *into* nature for the cycle to happen all over again.' (S15)
Transformation	**-Location Event Structure Metaphor**	
	Changes of Form of Energy Is Movement into (out of) Containers	'in the process light energy is *converted to* chemical energy.' (S10)
	Energy in Some Form Is a Resource	'Other animals the first *source* of energy is sun and then it is converted into chemical energy' (S6)
Conservation	**-Object Event Structure Metaphor**	
	Energy State is Amount of Substance	'At each stage of a food web *the majority of* chemical energy is transformed to other forms such as temperature, and does not stay inside the ecosystem.' (S5)
Degradation	**-Object Event Structure Metaphor**	
	Change of Energetic State of System Is Loss of Energy from System	'As it moves, *90% is lost* via heat' (S1)

The categories and conceptual metaphors identified in the textbooks were sufficient to categorize the expressions written by the students. To make sense of energy transfer, energy conservation, and energy degradation the students used the Object Event Structure metaphor and elaboration of it in terms of containment. To make sense of energy transformation the student used a sub mappings of Location Event Structure metaphors and understanding it as a resource. The frequency of students' expressions reflecting each aspect of energy and the proportion of those expressions out of the total number of student generated expressions are presented in Table 7 below. Following this will be Table 8 showing the frequencies of students' written expressions reflecting specific conceptual metaphors utilized to construe the different aspects of energy. The proportion in which the conceptual metaphors appear in the students' writings is also presented in relation to the total number of metaphors of each energy aspect reflected by the metaphors.

Table 7

Frequency of Students' Expressions Reflecting Each Aspect of Energy and their Proportions out of the Total Number of Expressions

Aspect of Energy	Frequency	Proportion
Transfer	42	0.67
Transformation	16	0.25
Conservation	3	0.05
Degradation	2	0.03

Table 8

Frequencies (f) of Conceptual Metaphors Reflected by Students' Written Expressions (SE) and their Proportions (p) out of the Total Number of Students' Written Expressions Describing Each Aspect of Energy

Aspect of energy	Construal type	S1	S2	S3	S4	S5	S6	S7	S8	S9	S 10	S 11	S 12	S 13	S 14	S 15	Total SE	
																	f	*p*
Transfer	Energetic State Is a Possession	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0.02
	Change in Energetic State Is Movement of a Possession	1	2	4	1	0	1	1	2	3	1	3	1	1	1	4	26	0.62
	Caused Change in Energetic State Is Transfer of a Possession	1	1	0	0	0	0	0	0	0	0	0	0	0	3	1	6	0.14
	Energetic State Is Content of a Container	2	1	0	1	0	0	1	0	0	0	0	2	0	0	0	7	0.17
	Change of Energetic State Is Movement into (or out of) a Container	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0.05
Transformation	Forms of Energy Are Locations/ Containers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	Changes of Form of Energy Is Movement into (out of) Containers	0	0	0	0	1	1	2	0	0	1	0	0	0	0	0	5	0.31
	Accessing Stored Energy Is Removal of Restraint	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Energy in Some Form Is a Resource	0	0	0	0	0	2	4	1	0	1	0	1	0	1	1	11	0.69
Conservation	Energy State Is Amount of Substance	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	3	1
Degradation	Change of Energetic State of System Is Loss of Energy from System	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	1

All of the students wrote metaphorical expressions that describe transfer of energy (f=42 expression). The expressions were distributed among the sub mappings of the Object Event Structure metaphor: Energetic State Is a Possession, Change in Energetic State Is Movement of a Possession, Caused Change in Energetic State Is Transfer of a Possession, Energetic State Is Content of a Container, and Change of Energetic State Is Movement into (or out of) a Container. Eight students referred to energy transformation in their writing and the number of metaphorical expressions written was 16 expressions distributed among the sub mappings of the Location Event Structure metaphor: Changes of Form of Energy Is Movement into (out of) Containers and Energy in Some Form Is a Resource; where more than half of the expressions involving transformation reflected Energy in Some Form Is a Resource (p=0.69).

Three expressions were written by two different students to make sense of energy conservation and all expressions reflected Energy State is Amount of Substance. The expressions included referred to the *majority* of energy, *shared amount* of energy and an expression referring to animals ‘not getting *all* the energy’. Only two expressions, written by S1 and S14, were identified to reflect energy degradation in terms of Change of Energetic State of System Is Loss of Energy from System.

The conceptual metaphor most frequently reflected in students’ writing was: Change in Energetic State Is Movement of a Possession (p=0.62) where 14 out of 15 students wrote expressions reflecting this conceptual metaphor. Thirty expressions reflected how energy is transferred in an ecosystem with high focus on feeding relationships that lead to this transfer. Among the sub mappings of the Location Event Structure metaphor utilized by the students to describe energy transformation Changes of Form of Energy Is Movement into (out of) Containers was the least frequently used (p=0.31) compared to Energy in Some Form Is a Resource (p=0.67).

It is noted that the most frequent appearance of expressions that construe Change in Energetic State Is Movement of a Possession (p=0.62) in the students' writing reflects the fact that the highest proportion of the expressions identified in all the textbooks reflecting energy transfer also construe Change in Energetic State Is Movement of a Possession (p=0.49). The highest frequency of expressions found to describe energy transformation in the textbooks mostly reflected Energy in Some Form Is a Resource (p=0.53). The same thing was also noted in students' writing, where the highest frequency of expressions recorded describing energy transformation was for Energy in Some Form Is a Resource (p=0.69). The fact that only two students wrote three expressions only with reference to energy conservation (p=0.05) and two students wrote two expressions about energy degradation (p=0.03) is consistent with the low frequency appearance of metaphorical expressions in all textbooks describing those two aspects of energy, 0.1 for energy conservation and 0.03 for energy degradation (Table 5).

Analysis of Interview Transcripts

The questions in the interviews were divided into two sets. In the first half of the interview, each student was reminded of the expressions they wrote (that were identified in analysis to include a metaphorical construal of energy) and asked to elaborate on those statements that described what happens to energy in an ecosystem. The students had to explain further what these statements meant. The next set of questions were intended to explore the students' metalinguistic understanding of metaphors related to energy. Students were first asked if they really believed energy is a substance-like entity. Then they were exposed to a sentence used in everyday English containing the same verb that expressed a parallel metaphor to that which appeared in the students' expressions. For example, if a student said that 'light energy is transformed into chemical energy,' they were asked about their understanding of a sentence such as 'The boy transformed his painful memories into lessons.' and whether it is similar to the sentence that they had written. The student's answer was expected to reveal his/her awareness of the metaphorical nature of the sentence. Follow up questions were then asked inviting students to compare the two statements and reflect on the metaphorical nature of the sentences e.g. 'How is this way of speaking similar or different to when you refer to light energy is transformed into chemical energy?'

The segments in the interview transcripts that appeared in the students' explanations or elaborations of the statements they used in their writing were coded through a process of open-coding using a constant comparative method. Nine coding categories emerged that capture the nature of students' understanding of energy as reflected in their explanations. The categories that were deduced through this process were the conceptualization of energy as (1) a substance contained, (2) a substance transferred, (3) a substance collected, (4) a conserved amount of substance; they also (5) explicitly referred to energy as a substance and (6) conceptualized energy as wasted, (7) emphasized transformation of energy and other entities, (8) understood energy as a process and (9) were unsure of the use of some words.

The explanations of the students in the first four categories reflected an understanding of energy contained in sources, energy transferred from one agent to another, and by feeding relationships between organisms. All of the interview segments coded in those categories reflected sub-mappings of the Object Event Structure metaphor. They expressed their ideas in statements very similar to statements that appear in textbooks. Twelve students clearly explained that energy is transferred by eating other organisms. The expressions written by most students were not far or different from expressions used in the textbooks when describing how energy is transferred between organisms e.g. compare ‘Consumers are organisms that get energy by eating producers or other consumers’ (*Science Fusion: Ecology and the Environment*, p.90) and ‘Energy is shared between animals in food webs from producers to consumers’ (S5). Most of the statements made by students when describing energy transfer, like the statements in textbooks, reflected Change in Energetic State Is Movement of a Possession and Caused Change in Energetic State Is Transfer of a Possession. The students’ elaborations in the interviews of such statements revealed understanding of energy transfer as a result of exposure to such metaphors in textbooks. Thirteen students described energy as contained in an agent at least once in the elaboration they gave in the interviews even though only 3 students wrote expressions that reflected Energetic State Is Content of a Container. Examples of students’ statements that construed Energetic State Is Content of a Container include ‘Energy in an ecosystem is produced by the process of photosynthesis’ (S12) and ‘Without energy in our body we can’t do anything.’ (S12).

However, the categories in which the students explicitly referred to energy as a substance, energy wasted, transformation involving energy and other entities, and student unsure use of words, revealed some misconceptions and shallowness in understanding, especially regarding aspects of energy such as transformation, conservation, and degradation. Seven students mentioned energy explicitly as something like sun, glucose, energy being decomposed, and given to plant by soil or like a fertilizer.

The interviews did not reveal any depth of understanding by students of energy transformation. Ten students did not provide any explanation of energy conversions. Four students mentioned transformation in their answers but were not able to explain it, suggesting they were just repeating what they read or heard. The following exemplifies this:

> Researcher: And how is energy transformed into chemical energy?
>
> S7: Mrs. I… to be honest I don’t really remember how and I didn’t really read on it because I believe they told us not to read had to write what we know.

None of the students were able to explain energy transformation, but simply produced statements like ‘Light energy is converted to chemical energy’ (S10). When asked if something is transforming into something else S10 answered ‘yes’ and described light energy as ‘catchable’ and chemical energy as ‘added to something’. S2 said that energy transformed to sugar and S13 said that energy is used to make apples. S11 mentioned that plants ‘produce’ their own energy to explain what happened to the energy they get from the sun. S12 used the phrase ‘produce energy’ and when asked how this happens, answered that she did not know why they used the word ‘produced’. Most of the phrases that students said they did not know how to explain or why they used them referred to forms of energy. However, the ten students who wrote expressions that reflected Energy in Some Form Is a Resource showed understanding of energy forms being sources of energy.

The analysis of the interviews revealed a very weak understanding of energy conservation and degradation. Four expressions were given by four students, S5 and S9, whose expressions reflected energy conservation and S1 and S14, whose expressions reflected energy degradation. When S5 was asked what she meant by the *majority* of energy, she was not able to give a clear answer and just said that a big amount will be transformed and the rest will not with no further elaboration. S9 used the phrase ‘does not get *all* energy’ and said in the interview that the rest goes to waste. In the interview S1 was not able to explain how is the 90% of energy, he mentioned in his writing, *lost* via heat. When asked about what she meant that energy *is lost*, S14 said that the rest of energy stays in the soil or goes to air. S11 did not write expressions describing energy conservation or degradation, however, he mentioned the percentage of energy being transferred between organisms. In the interview when S11 was asked about what happened to the rest of the energy in this case, he said that it stays in the roots.

One of the students, S7, mentioned different forms of energy a lot in the writing. S7 showed understanding of different forms of energy as resources, such as mechanical and thermal energy. S7 was able to explain transfer of energy as organisms take energy from the sun or by eating other organisms using expressions that reflected sub mappings of the Object Event Structure metaphor. However, when it came to explaining expressions about how energy from the sun is transformed into chemical energy, S7 restated that energy is transformed into chemical energy but did not remember how. When asked about what is meant by chemical energy S7 said that she is not quite sure. S7 seemed to think of energy and chemical energy as two different things where energy cannot be used and chemical energy could. There was one moment in the interview when S7 gave an explanation about energy as a process as shown in the transcript below:

Researcher: And one more question how is mechanical energy and thermal energy, how are they similar or different? What do you mean by mechanical energy or thermal energy?

S7: Ms. they're similar cause they're both types or processes of energy like eh happening. And ehh they like eh they're both they're both different by the way that they happen. بس انو كمان they're both energies and they both give energy بس انو they're different in the process how it happens.

In the second half of the interviews, the follow up questions explored students' awareness of the metaphorical nature of the energy metaphors they used. After asking the students about the expression they wrote they were presented with a similar everyday English expression and asked about how well they are able to understand the metaphorical nature of expressions in English too. e.g.

Researcher: So you said 'takes energy from it' does the rabbit really take something from the carrot?

S9: Eh eh yes the energy.

Researcher: When energy is taken from the carrot, do you really believe something is leaving the carrot to the rabbit?

S9: Something is leaving the carrot? Well if it's eating the carrot… ehhhh maybe.

Researcher: People say 'The girl takes her eye color from her mom' do they mean she took the color from her mom's eye?

S9: The girl takes the eyes of her mom's color? Ah well not like take انو like take them. Ehhhh but can look like them.

All of the students answered ‘yes’ when they were asked about whether they considered energy as a “thing”. For example, when S12 was asked if she believed that a “thing” is in our body when she wrote the phrase ‘energy *in* our body’, she explicitly said that energy is “like very small particles or nutrients” *in* our body. All of the students gave literal explanations to the energy expressions except for one student, S1 who gave literal explanations to all the expressions he made with the exception of one expression. When S1 was asked whether he thinks something is moved up in the statement ‘Since plants are everywhere, herbivores and carnivores *move* the energy up the food chain to the top’, he answered that it is a metaphor for saying that energy is transferred through the predators and not physically upwards. This was the closest any of the students referred to any statement about energy as metaphorical.

When asked about the everyday English metaphors, ten out of 15 students showed awareness of the meanings intended by all of the English metaphorical expressions they were presented with, however, without explicitly mentioning that they were metaphorical. The following exemplifies this:

Researcher: People say ‘Put yourself back together’ do they really mean something will be placed together again?

S15: No

Researcher: How does this compare to ‘put all energy back in nature’?

S15: So um as I said earlier when the decomposers decompose the energy is put back into nature and all that. بس when someone tells you to put back to put yourself back together, they don’t actually mean it. You’re not like broken or you’re انو your body isn’t broken or um it’s it’s not gonna like you know decom

… انو it's not gonna like a… انو it does …you don't actually put yourself back together. It's it's like انو like انو cheer up your mood … something like that.

S1 was the only student to explicitly refer to four out of the six English expressions he was presented with as metaphors e.g.

Researcher: People say 'We are carrying burdens from the past and this is a lot to handle' Do they mean that they are carrying something?

S1: It is metaphorical.

When asked about the statement 'My child moves up a grade' S1 said that it does not mean the child is physically moving, but he did not mention that it is a metaphor. In the last English expressions presented to him 'In the library quietness is everywhere.', S1 said that it means that silence is *in* the library.

Student 7 showed awareness of the metaphorical language of all English expressions except for one that she understood literally. The coding of the segments of the second part of the interview also revealed that 4 students did not understand any of the metaphorical expressions and explained them literally with very brief explanations. It was noted that those students were not fluent in English and were giving very brief explanations; their answers mostly consisted of 'yes' or 'no' with no further elaborations.

When the students were asked how the energy expressions they wrote were similar or different to the everyday English expressions they were presented with, 11 students described them as different since they were aware of the metaphorical meanings of the English expressions but understood the energy expressions literally. For example:

Researcher: People say 'Knowledge is transferred through group work' is knowledge really moving between people when they work together?

S2: No. It's just passing on بس it's not it still mental. It's not actually eh pas eh transferring.

Researcher: How does this compare to 'ATP transfer energy'?

S2: Well eh when ATP is transferring energy it's physically giving them to another place while if you're gonna eh transfer thoughts it's not you're not actually transferring anything; you're just sharing a mentally a mental image.

The rest of the students were not able to give relevant comparisons intended by the researcher.

Students participating in the study were told that they were allowed to use Arabic in their explanation if they felt they need to. Some students used words such as انو (That) هيك (this way) بس (but) يعني (it means) through the sentences they gave however their description of energy was always using English words. S12 was the only student to express herself with long segments of Arabic words but would switch to English whenever the word energy came up in the explanation e.g. 'don't know like Mrs. ' بس نحن ناكل بسير عنا انو ال Energy (when we eat we have energy), بس ناكل او بس نشرب هيك من كون عم نغزي حالنا ال energy (when eat or drink we will be nourishing ourselves from energy) بتسير عنا. (we start to have) I don't know if you understood me بس (but) I tried.'

In summary, the explanation students gave fell into the following categories: energy understood as a substance contained, a substance transferred, a substance collected, energy conserved as an amount of substance, explicit refer to energy as a substance, energy wasted, and transformation involving energy where all go under the broader theme of energy is a substance. All the segments of the interviews that went under this broad theme highlighted that the substance metaphor supported understanding of energy as found and accumulated in objects and that it can be transferred between objects. It was noticed through some of the explanations given by the students that this use of the substance metaphor revealed some misconceptions about containment, transfer and degradation of energy as considering energy a substance. Meanwhile, although 17 expressions written by eight students were classified as utilizing the Location Event Structure metaphor to make sense of energy transformation, the interviews revealed some misconceptions about transformation. Even when some students used sentences or phrases that mirrored statements presented in the textbooks about energy transformation, the students were not able to elaborate on their answers and many times mentioned that they did not know why they used a word or phrase.

Exploring the metalinguistic understanding of metaphors related to energy showed that the ELLs in this study were able to understand the metaphorical nature of many English sentences. Most of the students were able to explain that those sentences were not intended to be understood literally. However, the extensive and implicit use of the energy metaphors were not generally appreciated as metaphorical.

CHAPTER 5

DISCUSSION

In this chapter, the findings will first be discussed in relation to the literature. The chapter then addresses the limitations of the study and finally discusses the implications of the study for future research and practice.

Discussion of Results

In this section a discussion of the findings of the analysis of metaphorical expressions in textbooks, students' writing, and students' elaborations on their writings in interviews in relation to the literature is presented. The first subsection addresses the metaphorical expressions used in textbooks in relation to the literature on conceptualization of energy in the field of energy from a conceptual metaphor perspective. In the second subsection a discussion is presented that compares the energy metaphors used by students with the metaphors found in textbooks and discusses the findings in relation to previous studies that examined student written metaphors and analogies about energy. The findings are then related to hypothesized learning progression towards conceptualization of energy. The last subsection discusses the results of analysis of the interviews conducted which addressed the students' conceptualization and metalinguistic awareness of energy metaphors. All the findings of the study will be discussed in relation to research on teaching of metaphorical language to ELLs to suggest instructional and research implications.

Metaphorical Expressions in Textbooks

As mentioned in the previous chapter, most of the expressions containing the word energy found in all textbooks analyzed were identified as metaphorical (only 13 out of 120 expressions were not metaphorical). The expressions identified in the textbooks of grades four, five, and seven addressed energy transfer, energy transformation, and energy conservation. Degradation of energy, however, was only dealt with in the 7th grade textbook with a very limited number of expressions reflecting Change of Energetic State of System Is Loss of Energy from System. Metaphorical expressions in all textbooks, addressing energy transfer, conservation, and degradation reflected the Object Event Structure metaphor and an elaboration of it in terms of containment. All of those expressions construed energy as a substance-like entity. The rest of the expressions that addressed energy transformation reflected the Location Event Structure metaphor and elaborations in terms of a resource schema, and a force dynamics schema.

The number of expressions dealing with the different aspects of energy differed between the different grades. The proportion of expressions that dealt with energy transfer increased from the 4th grade textbook to the 5th grade textbook and the 7th grade textbook. The conceptual metaphors describing energy transfer most frequently reflected in the 4th grade textbook were Energetic State Is a Possession and Change in Energetic State Is Movement of a Possession. In the textbooks of grade five and seven the expressions describing energy transfer mostly reflected Change in Energetic State Is Movement of a Possession. On the contrary, the highest number of expressions dealing with energy transformation was identified in 4th grade textbook compared to the 5th and 7th grade textbooks. Most of those expressions in the 4th grade textbook reflected Changes of Form of Energy Is Movement into (out of) Containers and Energy in Some Form Is a Resource. The proportion of energy metaphors that involved energy conservation, reflecting Energy State Is Amount of Substance increased up the grades but remained very limited in number.

The mappings identified in the textbooks analyzed mainly highlight energy as a substance-like entity. To conceptualize energy transfer, transformation, conservation and degradation energy was construed as something exchanged between entities, changing forms, conserved as an amount of something, and lost from a system. Construing energy as a substance-like entity has been found in other analyses of scientific texts (Amin, 2009; Dreyfus et al., 2015; Scherr, Close, McKagan, Vokos, 2012). The findings of the current study are consistent with the findings of Amin (2009), where the analysis of the university level Feynman Lectures on Physics revealed that the expressions describing many aspects of energy such as conservation and transfer were understood via metaphorical projections mainly structured by the Object Event Structure conceptual metaphor.

The use of implicit substance metaphor to highlight the aspects of energy identified in this study was also in line with findings of Scherr et al. (2012) where verbal and visual representations of energy in expert discourse was structured in terms of the notion of quasi-material substance. The substance metaphor was found to be powerful in conceptualizing energy as conserved, existing in objects, and transferred. This reveals an extensive use of the substance metaphor used in science books and by physicists which is considered a resource for deepening the understanding of students about energy, however, with some limitations that will be discussed later.

The findings of the current study showed that energy was treated as a substance in scientific discourse and this was similar to the findings of Lancor (2014a). Lancor (2014a) presented a comparison of the extent to which conceptual metaphors are used across different science domains. Lancor examined the discourse used to explain the role of energy metaphors in biology, physics and chemistry and, similar to the results of the current study, found that the same metaphors that construe the different aspects of energy appear in all domains but to a different extent. It was noticeable that the *energy flow* and *energy as a substance that can be carried* language was used repeatedly in biology textbooks (Lancor, 2014a) and energy construal that reflected transfer of energy was used more frequently in the 5^{th} and 7^{th} grade textbooks that described energy in ecosystems. Unlike contexts of physical science, biology books tend to include language that indicates energy is *lost* from systems reflecting energy degradation (Lancor,2014a). This was also evident in the analysis reported in this study that revealed only three energy metaphors involving energy degradation in the 7^{th} grade textbook.

The results of the current study were not consistent with results from other studies, when it comes to energy conservation. Metaphors reflecting energy conservation were emphasized in physics and chemistry books more than biology books in the study by Lancor (2014a). Hartley et al.'s (2012) study also revealed that energy conservation was less frequently addressed in biology textbooks while language that deals with energy conservation was used in all physics and chemistry books. However, the study reported here showed that the number of metaphors construing energy conservation was very low in the physical science textbook of 4^{th} grade (p=0.05) and increased in the 5^{th} grade biology textbook (p=0.1) and the 7^{th} grade biology textbook (p=0.13).

The prevalence of conceptual metaphors across different textbooks and in scientific experts' reasoning was also reported by studies that examined scientific discourse addressing related concepts of energy: heat and entropy (Amin et al., 2012; Jeppsson et al., 2013). Sub-mappings of the Object Event Structure metaphor and Location Event Structure metaphor are reflected in many metaphorical expressions that construe those concepts. The results of all studies –including this one- support the claim that no one metaphor is enough on its own to conceptualize a complex and abstract concept. The analysis of scientific discourse by different researchers showed that the concept of Energy is understood in terms of sub conceptual experiential knowledge gestalts reflected in the mappings presented above. These experiential knowledge structures – available to all from an early age and can be assumed to be available to all students – contribute to the development of the scientific understanding of energy (e.g. *gains* energy -Change in Energetic State is Movement of Possession, the energy an object *has* -Energetic State is a Possession)

Looking at the proportions of expressions that address certain aspects of energy in the different grade level textbooks, we can tell that there is an emphasis on some aspects more than others in different grades. The proportion of expressions dealing with energy transformation identified in the 4th grade textbook was close to expressions dealing with energy transfer. The use of expressions describing energy transfer increased in grades five and seven while the use of energy expressions describing transformation decreased. The pattern in the 5th and 7th grade textbooks was different with a much higher focus on energy transfer than any other aspect of energy. Change in Energetic State Is Movement of a Possession was the most frequently reflected metaphor among all the metaphors describing energy transfer in all textbooks. However, although energy transformation was described less in the 5th and 7th grade textbooks it was noticeable that expressions reflecting Energy in Some Form Is a

Resource had the highest proportion, in the 5th and 7th grade textbooks, among all the conceptual metaphors that described energy transformation.

Introducing energy sources and forms of energy and energy transformation in lower classes could be considered as an attempt to give students a tool to track energy changes, energy interactions, and energy conservation between systems later on. This appears to be in line with how Neumann, Viering, Boone, & Fischer, (2012) defined the lower anchor of their learning progression for energy, where students come to understand how energy comes in different forms and from different sources first. The high proportion of metaphors that reflected energy forms and energy transformation in the 4th grade textbook was in line with the lower anchor of the learning progression of energy defined by Neumann et al. (2012). The focus in higher grades shifted towards energy transfer and later to energy conservation in the 7th grade. This again mirrored the sequence of concept development hypothesized in the learning progression where conception of the aspects of energy progresses from energy coming in different forms towards understanding of energy transformation and transfer until a full comprehensive understanding of energy including energy degradation and conservation. The use of metaphors that refer to energy forms and energy transformation could help in further addressing energy conservation when energy changes are tracked (Lancor, 2014a; Neumann et al., 2012; Optiz et al., 2017)

Comparison of Textbook Metaphors and Students' Use of Metaphors

The analysis of the students' writings revealed a small number of expressions in which a few students used energy to refer directly to concrete things, a construal absent in textbooks. One student for example said that sugar is energy, 'turning it into sugar a.k.a energy'. The rest of the metaphorical expressions describing energy identified in students’ writing could all be categorized into the same sub-mappings reflected in expressions about energy recognized in the textbooks. The expressions reflecting energy transfer, conservation and degradation were distributed among the sub mappings of the Object Event Structure metaphor and the expressions reflecting energy transformation were distributed among sub mappings of Location Event Structure and resource schema. Transfer of energy was addressed in the writings of all students participating in the study while energy transformation was addressed by ten students (out of 15) only. The least number of metaphorical expressions written dealt with energy conservation and energy degradation. Most of the expressions addressing energy transfer reflected Change in Energetic State Is Movement of a Possession. The expressions that addressed energy transformation mainly reflected Energy in Some Form Is a Resource and only five expressions referred to change of forms of energy. The results implied an extensive use of energy as a substance metaphor by all students.

In the current study, the students were asked to describe what happens to energy in an ecosystem and it turned out from the results that all the writings of the students contained implicit metaphors of energy. All the metaphorical expressions were categorized into the same conceptual metaphors identified in the textbooks they are exposed to. However, some mappings reflected in textbooks did not appear in the categorization of students’ written expression -namely Forms of Energy Are Locations/ Containers and Accessing Stored Energy Is Removal of Restraint. This finding of the study can be added to the evidence from previous research that showed that students (even if of older grades) of different expertise level use conceptual metaphor in problem solving and reasoning about entropy. Jeppsson et al. (2013) and Jeppsson et al. (2015) explored the conceptual metaphors used by PhD physics and chemistry students and conceptual metaphors used by undergraduate chemistry students respectively while they solved the same problems. It was reported that both groups of students used conceptual metaphors to solve problems, where the PhD students used the conventional metaphors found in textbooks, but used them productively extending their use in novel ways depending on the problem. The undergraduate students however used less conceptual metaphors and interestingly enough those students' use of conceptual metaphors were repetitions of metaphorical expressions they were exposed to in lectures and textbooks.

Several studies have targeted the use of conceptual metaphors that addressed different aspects of energy. They compared the metaphors used by students to metaphors found in textbooks (Lancor, 2014a, 2014b; Wernecke et al., 2017). The findings of the current study provide similar evidence to the findings of most of those studies. It is interesting to note that conceptual metaphors used to conceptualize aspects of energy by the 7^{th} grade students in this study are also those identified in 4^{th}, 5^{th}, and 7^{th} grade textbooks. This finding is similar to the findings of Lancor (2014a, 2014b) where metaphors common in pedagogical discourse were used by students in different contexts to conceptualize energy. The fact that the majority of expressions written by students in the current study addressed transfer of energy was also in line with the finding of Lancor (2014b) which revealed that most of the analogies generated by biology students in the context of ecosystems contained evidence of energy transfer and contained evidence of sources of energy (Lancor considered sources of energy as an aspect on its own).

In another study Wernecke et al. (2017) analyzed biology textbooks' use of metaphors specifically describing energy transfer through an ecosystem: energy flow and energy loss. Students' applications of those metaphors were then examined through writings describing a diagram showing energy flow through a forest to see if they are adopted and used in the intended way. The conditions for Wernecke et al.'s study were different than that of the current study, where students were given the prompt directly after class instruction and exposure to a PowerPoint presentation containing the specific targeted metaphors. Some results of the Wernecke et al.'s study, however, were comparable to the present results. An important point to raise is that the metaphors in the textbooks analyzed by Wernecke et al. were also implicit and were not marked explicitly as metaphors as was revealed in the analysis of the expressions describing energy in the textbooks targeted in the current study. Some of those metaphors were used correctly by students while others were not. The results showed that the energy metaphor *energy flow* was the metaphor most frequently used by students as they described energy transfer through ecosystems. There seemed to be an overgeneralization of the Energy Is a Substance metaphor by treating energy flow as a substance by some students where one student said that 'the secondary consumer losses 0.5% energy flow through dead biomass.' Although the energy loss metaphor was used by the students in Wernecke et al.'s study more frequently than the students of the current study, there was no evidence that the students' conceptions of energy loss and conservation were very conceptually meaningful (and thus not obviously correct or incorrect). Wernecke et al. considered this to be a sign of phrases being repeated as read in textbooks or resources provided to students, without full understanding of the concept. This largely unproductive use of conventional metaphors to which students are exposed in textbooks with limited conceptual understanding is similar to the pattern of use found in this study and revealed more clearly through the analysis of the interviews with students (see below).

Discussion of Findings from the Analysis of Interviews

The interview questions were divided into two parts. The first part explored students' elaborations on the expressions they used in their writing and required them to further elaborate on the explanations they gave regarding the aspect of energy addressed. The second set of questions probed students' metacognitive awareness of the metaphorical nature of their use of the word energy.

Students' Elaborations on Energy Metaphors. The segments from the first part of the interview that included students' elaborations on the energy metaphors they wrote were divided into nine categories. Four of those categories reflected an understanding of energy as having substance-like properties: a substance contained, a substance transferred, a substance collected, and energy conserved as amount of substance. All the statements in those categories indicated an understanding by students of energy contained in sources, energy transfer from one entity to another, and energy passed between organisms by feeding relationships. The expressions students used were similar to expressions found in textbooks and they provided evidence for students' understanding of energy transfer and sources. The metaphors students wrote showed that students were at more ease writing about energy resources and how energy is transferred. The explanation they gave in the interviews of expressions reflecting energy transfer showed that the substance metaphor, extensively used to describe energy transfer, facilitated this concept development. Although very few students wrote expressions reflecting Energetic State Is Content of a Container, most of the students mentioned energy contained in sources in the elaborations they gave in the interviews.

The other four categories -which referred explicitly to energy as a substance, energy wasted, energy transformation and students being unsure of words used- all exposed misconceptions students have about energy transformation, conservation and degradation. Although students were aware of different forms of energy in different resources, many did not refer to energy transformation when describing what happens to energy in an ecosystem. Six students referred to energy changing form but were not able to give a scientifically sound explanation of what they wrote. Many of the expressions written were repetitions of expressions students encountered in textbooks and when they had to explain what was meant by those expressions they failed to do so.

Again the pattern in which the understanding of the different aspects of energy appears in students' explanations given in the current study shares features with the results of the study by Neumann et al. (2012) but reveals some differences. Neumann et al. expected that students would first develop an understanding of energy forms and sources and then develop an understanding of transfer and transformation and later on gain a comprehensive understanding of energy when they conceptualize energy degradation and conservation. Neumann et al.'s study, which addressed students in grades six, eight, and then, examined to what extent the hypothesized learning progression actually described the development of students' understanding of the energy concept. The findings of their study partially confirmed their hypothesis. They found that students of grade six indeed develop an understanding of energy forms and sources initially and students of grade eight (who have developed an understanding of energy forms and sources also) correctly solved questions about transfer, transformation and energy degradation. In contrast, in this study students (who are close in age to students of grade 8) showed understanding of sources of energy and referred to energy transfer but did not reveal understanding of transformation or degradation in parallel. The limited number of expressions written about transformation and the inability of the students to explain transformation of energy or elaborate on the difference between different forms of energy, highlighted that students did not develop a scientifically sound understanding of energy transformation although they showed a sound understanding of energy transfer. No evidence of understanding of energy degradation was observed by the students' elaborations in the interviews.

The difference in the finding of Neumann et al., (2012) and the current study could be due to the difference in the context in which the questions were asked and the fact that the questions in Neumann et al., (2012) were multiple choice students, where students chose the correct answer, and not a prompt where students wrote freely about energy in an ecosystem and later elaborated orally on their answers in an interview. Having questions and a set of answers from which to choose might not be enough to assess how students' conceptualized the aspects of energy since they can be choosing familiar phrases and words they were exposed to in class. This assumption is supported by the fact that some of the students' writings in the current study contained expressions about certain aspects of energy like transformation and degradation that students failed to explain correctly.

There was one student, S7, who was able to describe thermal and mechanical energy as forms of energy that are different due to the process or way they come to be. Since S7 mentioned that she read about energy, so it can be suggested that this developing view of energy could be enhanced in students of this age level through planned instruction.

The results of the current study were similar to some of the results observed by a prior qualitative study on students' conception of aspects of energy in a biological context by Opitz et al. (2017). Opitz et al. however, examined the development of conceptions of energy across different grades. The current study only explored 7th grade students' understanding of energy. The results of both studies showed that understanding of energy sources and transfer are accessible to 7th grade students, although it is noted that some students in both studies thought that soil and water were also sources of energy in addition to food and sunlight. Both studies show that 7th grade students used an acceptable view of energy transfer in systems although there seems to be an overgeneralization of the substance metaphor in the students' conceptualization of energy. The current study showed that students faced problems in using expressions addressing energy transformation and in explaining energy transformation if mentioned. The results by Opitz et al. (2017) reported a better understanding of energy transformation with students at a similar grade level.

The energy degradation and conservation were hardly addressed in the students' writings and interviews as reported in the findings of the current study. Opitz et al. (2017) reported the same findings about energy degradation and conservation with students of grade seven. In the current study, even when students who had referred to energy metaphors addressing those two aspects in their writing were directly asked about what happens to the rest of energy, they were not able to explain energy degradation in line with the conversions of energy forms that took place. This result could be due to their undeveloped concept of energy transformation; as a result of the gaps students have, they will not be able to understand energy degradation (Neumann et al., 2012). It could also be because those two aspect of energy are not covered enough in school and the low proportion of metaphors in the textbooks describing energy conservation and degradation reflects this.

In sum, the findings of the current study revealed a very limited use and understanding of the metaphors that describe energy transformation, conservation and degradation. When energy transformation is not completely understood the conceptualization of energy degradation and conservation becomes harder (Lancor, 2014a; Neumann et al., 2012; Opitz et al., 2017). However, the low proportion of expressions used in the textbooks also suggests that those aspects of energy might not have been targeted enough in the classroom.

Students' Metalinguistic Awareness of Metaphorical Use of Energy. The results of the current study indicate that most students showed sufficient understanding of the metaphors from everyday English they were presented with. In contrast, all students gave a literal meaning to the metaphorical energy expressions they wrote and showed that they really conceptualized energy as a substance-like entity. The students were not able to recognize the metaphorical nature of the energy expressions they wrote, which in most cases mirrored the statements they were exposed to in the textbooks. It is worth noting here that all the energy metaphors in the textbooks students were exposed to were implicit and no explicit reference was made in the texts to their metaphorical nature.

The everyday English metaphors presented to the students in the interviews used the same source domain as the energy expressions written by the students but were used in everyday contexts -e.g. 'Knowledge is transferred through group work. How is this similar or different to energy transferred from organism to organism?' When asked to compare the English metaphors with the students' energy metaphors, most of the answers the students gave showed that they understood the meaning of the everyday English expressions as metaphorical (without saying it's a "metaphor" except for one student) and gave the energy expression they wrote a literal meaning; construing energy as a substance-like entity or *thing*.

Research supports the view that children are capable of understanding metaphorical language before the age of 10 or 12 (Vosniadou, 1987; Winner, 2017). The 7th grade students showing awareness of the metaphorical meaning of the English expressions in this study is consistent with such findings. The interviews conducted in the current study revealed that some students sometimes understood the metaphorical meanings of some English expressions and not others. This could be, as Vosniadou (1987) stated, due to difference in the children's "prior knowledge, the context in which the metaphor occurs, and the linguistic complexity of the metaphorical input" (p.34). So, the ability to understand metaphorical expressions in English language was evident for the ELLs in this study but could have been impaired due to factors of the linguistic complexity of some of the expressions used or the child not being familiar with the context of the metaphor.

If all the students showed sufficient comprehension of metaphorical expressions, why is it that none of them showed any awareness of the metaphorical nature of energy expressions, even though the language used and the phrases that are written about energy do not contain any apparent linguistic complexity. The aspects of energy presented in the textbooks are construed in metaphors that incorporate source domains consisting of knowledge structures that derive from sensorimotor experience which are all familiar to students. However, this challenge that appeared could be linked to the overgeneralization of the substance metaphor that was evident in the analysis of the energy expressions in both textbooks and students' writings and their shallow understanding of the conceptual domain.

The analysis discussed so far showed that implicit metaphorical language was prevalent in construing energy in textbooks analyzed in the current research as well as previous research (Amin, 2009; Amin et al., 2012; Jeppsson et al., 2013; Lancor, 2014a; Scherr et al., 2017). Students use metaphorical construal, similar to those used in scientific discourse, to describe aspects of energy (Amin, 2009; Lancor, 2014b, 2015; Wernecke et al., 2017) or heat (Jeppsson et al., 2015). The substance metaphor was reflected the most when conceptualizing energy whether in scientific discourse or students' explanations of energy. The fact that the results of the current study showed that students mostly addressed energy in their writings using metaphors that reflect the Object Event Structure metaphor and explicitly referred to it as a thing when asked to explain their understanding of the implicit energy metaphors they wrote, supports the findings of the studies referred to above. The substance metaphor was reported as powerful and pervasive resource for understanding energy in all studies referred to above (Amin, 2020) and the results of the current study are an added evidence to the usefulness of this construal in conceptualizing energy sources and transfer; however, caution has to be taken from this over use of the substance metaphor where students will incorrectly treat and understand abstract concepts such as heat and energy as a substance (Amin, 2020; Brookes and Etika, 2015; Lancor, 2014a, 2014b, Scherr et al., 2012) since they are not even aware of the metaphorical nature of the language they are exposed to.

Another important factor that can influence students' adoption of the substance metaphor is the fact that research has shown that reference to energy appeared in people's everyday English when analyzed from conceptual metaphor perspective (Amin, 2009). Energy in everyday discourse was addressed in terms of a resource stored, contained, and change in energy states as movement of a substance. Students' conceptions of energy can be traced to metaphors implicit in everyday language. Those are considered conceptual resources students draw on to construct the scientific understanding of energy.

The students in this study are ELL students whose first language is Arabic and are taught science through the English language. Those students' conceptions of energy are not only shaped by the resources in the English language they are exposed to. Those students are already potentially holding alternative conceptions of energy implicit in their native language. As reported in Lahlou (2020), the concept of طاقة for Arabic speakers and energy for English speakers are understood in terms of Energy is a Substance metaphor in both languages. This is reflected in the two meanings of the word -ability and source of power- in both languages. Therefore, it is important to keep in mind as was stated in Lahlou (2020) that 'Arab and English learners are then presumed to face the same difficulties in learning the concept concerned. More precisely, these learners may not understand the exact meaning of the concept ENERGY in science classes because of the pre-existing knowledge they have about this concept' (p.11). The students are already exposed to energy in terms of Energy Is a Substance metaphor in their native language out of school. In formal schooling and as ELLs those students are again exposed to extensive use of the substance metaphor when being taught about energy which could further hinder their conceptualization of some aspects of the concepts.

Limitations

This study has a number of limitations that must be considered. This study was conducted during the COVID-19 pandemic. This led to conducting the session in which students had to answer the writing prompt virtually. Although the students had to have their cameras on during this activity, a few typed their answer down on word and this might have allowed for some copying of phrase from online resources. Interviews being conducted virtually also made it difficult to determine whether students were not expressing themselves openly due to being unsure of their understanding or because they felt awkward about being in a one-on-one virtual interview.

Another limitation of the study was the fact that classroom talk was not observed to see if other resources were being presented to students. It would have enriched the study to explore the kind of expressions containing the word energy produced by the teacher that could potentially influence students' use and understanding of energy metaphors.

Moreover, the students' understanding of what happens to energy could be influenced by the symbolic representations and diagrams presented in the textbook, this study however was concerned with the linguistic information presented and how it is used by students (Swackhamer, 2005).

Finally, analyzing gesture is another missing element from this study (Dreyfus et al., 2015; Yamout, 2020). The analysis of gestures has been shown to help researchers make sense of the students' conceptions often not expressed in language, often including metaphorical understandings. This, however, was beyond the scope of this study.

Implications

This study examined the metaphors students used in their writings about energy in an ecosystem. This use of metaphors was compared to the conceptual metaphors reflected in energy expressions found in the textbooks students are exposed to. This study also provides one of the first analyses of metacognitive awareness of students of the metaphors used to describe energy in the context of biology. Since the students participating in the study are ELLs, their awareness of everyday English metaphors was also examined. The findings of the study could form a basis for deriving implications for practice and future research.

Implications for Practice

The results of the study show that some metaphors are picked up easily form the textbooks. The Object Event Structure metaphor reflects energy transfer in textbooks and is used frequently by students when describing energy in the context of ecosystems. Moreover, in the interviews, when students elaborated on the energy statements they wrote they tended to use more metaphors that reflect an understanding of energy as a containment and as sources. Students appear to have conceptualized the concept of energy sources and how energy states change as a result of this transfer of energy in interactions taking place in ecosystems. This implies that teachers can use Change in Energetic State Is Movement of a Possession, Caused Change in Energetic State Is Transfer of a Possession, and Energetic State Is Content of a Container as basis to explain and further develop understanding of transformation and degradation. As students learn about energy forms and sources in specific interactions associated with energy transfer, pointing out the salient changes associated with energy transfer can enhance understanding of energy transformation and conservation of energy (Swackhamer, 2005)

The students, however, frequently used the substance metaphor to describe energy transfer and often to think of energy- as a substance, in their elaborations during the interviews. Students' understanding of the concept of energy transformation, conservation and degradation was weak, however. So even if students were introduced as early as fourth grade to forms of energy and instructed that energy changes forms as a result of interactions, it seems that further elaborations and instructions that explicitly engage students in thinking about changes associated with energy sources and energy transfer (Neuman et al., 2012; Swackhamer, 2005) is necessary to facilitate comprehensive understanding of energy aspects.

A revised curriculum could invite teachers to facilitate the development of students' understanding of energy transfer in parallel with an understanding of energy forms and transformations. These findings can be interpreted in light of what Amin (2015) discussed where an aspect of conceptual change is the appropriation of metaphorical construals implicit in language. The point raised in this case is to include class discussions that point out what aspect of energy the metaphor used highlights and why it obscures other aspects. Teachers can also explicitly present familiar examples from children's early experiences that will evolve with instruction into scientifically valued concepts. This strategy was suggested by the learning progression by Lacy, Tobin, Wiser and Crissman (2014) when teaching students from 3rd grade till 5th grade about energy. The learning progression proposed by Lacy et la. includes an Energy Lens composed of questions that students should repeatedly ask themselves when exposed to different contexts involving the aspects of energy in order to learn about energy. For example, since students are familiar with moving marbles colliding, they could be exposed to such instances and ask themselves questions such as 'Where are there energy changes? Where did the energy come from? Where did the energy go?' Students in this situation see that one marble's energy loss is another one's energy gain. Teachers in this case would be building on a model of energy as a kind of 'stuff' that is transferred between objects. In similar interventions done by Lacy et la. students were given a twisted elastic band attached to a propeller. Students observe what happens when the elastic band untwists and identify observable indicators of energy changes when the propellers starts to move. In this way the students would be introduced to the elastic energy stored in the elastic band and recognize that the energy lost by the elastic band is gained by the propeller in a different form.

Being explicit about the metaphorical nature of the expressions and the relation of aspects of energy in interacting systems could help develop understanding of energy transfer and transformation which will make conceptualization of energy conservation and degradation easier (Neumann et al., 2012; Opitz et al., 2017). If students are not aware of the metaphorical nature of the expressions whether in everyday discourse or in scientific discourse, and appear to interpret these expressions literally, this raises a question on how metaphors should be approached when teaching about energy? Students' insistence on treating energy as a substance due to conceptions they form from everyday language and this seems to be enhanced and becomes hard to change when they are exposed to substance metaphors in scientific text. Energy cannot be discussed without referring to it as a substance (Lancor, 2014a) and the substance metaphors used are powerful in illustrating energy aspects (Amin, 2020). However, the results of this study and studies involving metaphors in science (Lancor, 2014b and other fields (Boers, 2000; Dong, 2004) proposed instructional approaches in suggest that teachers should be explicit about the metaphorical nature of the statements used to describe energy and this would then help to point out metaphors that highlight certain aspects and obscure others.

Implications for Research

Future research could make use of the findings of this study and extend it to examine the effect of students' awareness of metaphorical language in scientific discourse targeting energy. Research on how development of energy progresses with students aware of the metaphorical nature of energy expressions versus students exposed to implicit metaphors is suggested. Designing experimental research where different strategies of teaching about energy are tested against implicit use of metaphors of energy in textbooks is recommended. It might help to know if the students' unawareness of the abstract nature of energy is a factor that influences the development of the concept of energy. Is the excessive use of implicit metaphors inhibiting this progress?

Research on the effect of including awareness raising activities that call students' attention to the metaphorical nature of the language used to describe energy could be considered. The use of such activities was recommended by many studies to teach metaphors to second language learners (Hoang, 2012). In the field of science this could be examined to help reduce students' literal understanding of the substance metaphor. Explicitly discussing what aspects of energy are highlighted by some metaphor and what is obscured would help students think critically about how they understand energy.

The students in this study did not seem to know that energy was being given the properties of a substance to help describe how energy changes occur in interaction in ecosystem. No work has examined students' awareness of the nature of energy metaphors and its effect on their conceptualization of energy. This should be a point of focus for future research on exploring the effect of metaphorical awareness on the conceptualization of scientific concepts e.g. energy. In research on child development it was argued that explicitness of the metaphoric comparison and explicitness of the metaphorical grounds can facilitate metaphor comprehension (Vosiandou, 1987). In the context of teaching language to ELLs a study by Dong (20104) also recommended being explicit about metaphors to help students in reading comprehension and interpretation. In the field of economics Boers (2000) also highlighted that enhanced metaphoric awareness could facilitate in-depth reading comprehension of French students studying economics in English.

The development of students' conception is affected by how teachers are responding to difficulties students face in understanding energy metaphors and misconceptions they reveal. Observation of class sessions and analysis of the interactions taking place in class, between all the factors influencing the learning process, need to be investigated in addition to scientific discourse on energy.

Students are not only exposed to language in textbooks when learning about energy. Teachers turn to different representational tools, gesture and class discussions that involve metaphorical reasoning when explaining the lessons. Instead of teachers correcting the student' choice of words when talking about energy, it is suggested that they listen to and analyze what the students are trying to say (Daane, Haglund, Robertson, Close, & Scherr, 2018). In the study by Daane et al. (2018) teachers were introduced to conceptual metaphors in an attempt to increase their sense of usefulness of conceptual metaphors, so that later on they can understand students' ideas about energy. Teachers at the end of the activity were found to be enthusiastic about using this knowledge in the classroom when interacting with students. Teachers' awareness of the implicit messages those resources are conveying should be explored and targeted more in future research. This way the students' metaphors for energy can be resources for instruction in the classroom. They can be a starting point for teachers to activate the right image-schema or build on what the students already have in mind.

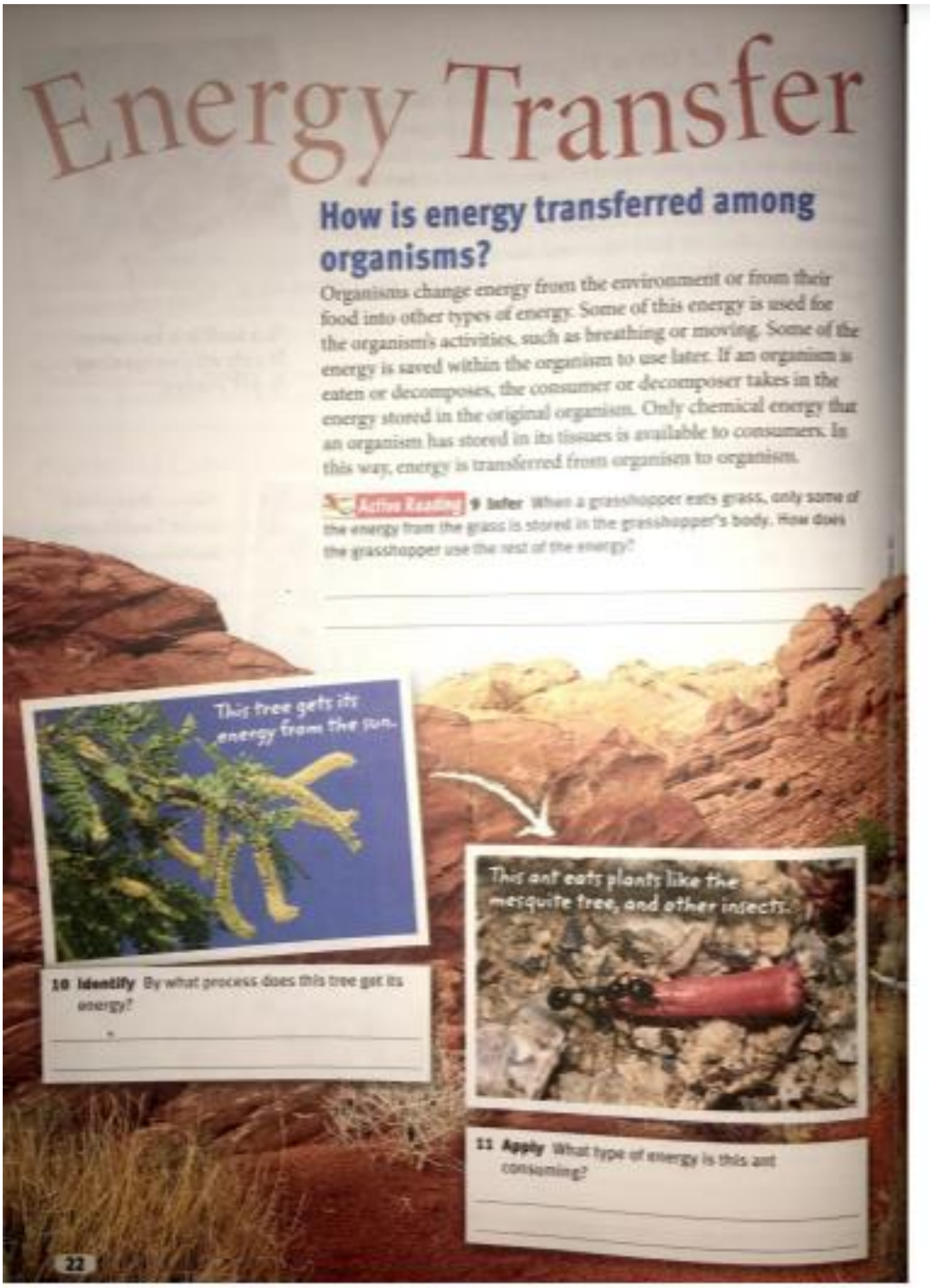
Conclusion

The aim of this study was to explore from a conceptual metaphor perspective the metaphors used in describing energy in the context of science textbooks and in students' writings about energy in ecosystems. Students' metalinguistic awareness of the metaphorical language of their expressions describing energy was explored through one-on-one interviews. The results of the study revealed that all of the expressions in textbooks and the majority of the expressions written by students reflected implicit metaphors. The expressions in textbooks and writings of students reflected sub mappings of the Object Event Structure metaphor and the Location Event Structure metaphor. Energy transfer, energy conservation and energy degradation were addressed in expressions reflecting the Object Event Structure metaphor and expressions addressing energy transformation reflected the Location Event Structure metaphor. The students appeared to be using energy expressions that mirrored the expressions found in textbooks, with a focus on expressions describing energy transfer. Although students were found to understand the metaphorical meaning of everyday English expressions, they offered literal interpretations of the energy expressions they produced. All of the students therefore, treated energy as a substance in the explanations they gave in the interviews.

Analysis of the results revealed that there was an overgeneralization of the Energy Is a Substance metaphor in students' understanding of the aspects of energy. This possibly led to weak development of the conceptualization of energy transformation, degradation, and conservation for students. The findings revealed above suggests that targeting students' awareness of the metaphorical language used to construe energy could support enhancing the acquisition of a more comprehensive understanding of energy in scientific contexts. Appropriation of metaphor construal and correct mappings between a source and target domain can enhance the learning of such an abstract concept like energy. Understanding the effects of explicit reflection on metaphorical meanings and what aspects of energy is highlighted and what is obscured is a rich area for future research. The teachers' role in the learning process, whether in terms of their awareness of the difficulties students face when using metaphors or in guiding learners to activate the right image schema at the right time, should also be considered for investigation in future research.

APPENDIX A

Sample of a Page from the 7th Grade Biology Textbook


Energy Transfer

How is energy transferred among organisms?

Organisms change energy from the environment or from their food into other types of energy. Some of this energy is used for the organism's activities, such as breathing or moving. Some of the energy is saved within the organism to use later. If an organism is eaten or decomposes, the consumer or decomposer takes in the energy stored in the original organism. Only chemical energy that an organism has stored in its tissues is available to consumers. In this way, energy is transferred from organism to organism.

Active Reading 9 Infer When a grasshopper eats grass, only some of the energy from the grass is stored in the grasshopper's body. How does the grasshopper use the rest of the energy?

This tree gets its energy from the sun.

10 Identify By what process does this tree get its energy?

This ant eats plants like the mesquite tree, and other insects.

11 Apply What type of energy is this ant consuming?

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APPENDIX B

Samples from Students' Writings

Student 7's writing

The Ocean

The ocean is the home to the smallest organisms like bacteria, as well as the world's largest living structure. And, the largest organisms live in it! Over seventy percent of earth's surface is water. As I used to read books about earth and oceans (that's why I picked the ocean) there are two types of energy produced, mechanical energy which is produced usually from waves and tides, and we have thermal energy which is produced from the sun's heat. Most waves carry energy with it. A lot of phytoplankton organisms are found at the upper part of the ocean which gain energy from the sun, and then transform it into chemical energy which they survive on. Other organisms like small fish and whales feed on phytoplankton. Derp creatures that live hundreds of meters away from the sunlight rays are more often to get their energy from "chemical energy", from the books I usually read I know about chemical energy and how it's usually produced or sometimes transformed but I don't really remember details. I remember something in one of the books that mentioned "chemosynthesis" . It's the process they use instead of photosynthesis as there is no light reaching this deep in the ocean. As for how deep is the ocean, it's known that it's about 36,070 feet and the deepest part of the ocean (which is 36,070 feet) is located beneath the western pacific ocean.

Student 14's writing

My ecosystem is the terrestrial ecosystem. In the terrestrial ecosystem, the main source of energy is the sun which gives off energy to the producers, example: trees, plants, and grass. Then animals such as cows, chickens, and all herbivores basically eat the producers for energy. Now 10% of that energy is passed on to the animals that ate the grass and 90% is lost. What about the carnivores? Carnivores eat animals to gain energy but they also only get 10%. And when the animals die, if their bodies get consumed by other animals they also gain 10% of the energy, or the animals just get decomposed into the soil and 10% of its energy is returned to the producers by the soil.

Student 13's writing

A lot of wild animals live in a forest such as a lion or a bear. In every forest there is a prey and a predator. Plants and other greenery are producers. Producers produce food using sunlight; they are also the first trophic level in a food chain. Next week there are the consumers such as elephants, horses, rabbits… there are some types of consumers and they are the omnivores, carnivores, herbivores, and decomposers who decompose the dead organisms. there are also two types of consumers that are the primary and secondary consumers. The primary consumers are the ones who only eat producers while the secondary consumers are the ones who eat other consumers and producers. All these are included in the food chain. The food chain starts from level on as a producer that get sunlight from the sun to produce food, second level are the primary consumers who eat producers, third level are the secondary consumers who eat producers and primary consumers, fourth and mostly lasts lever are the tertiary consumers who eat primary and secondary consumers. Let's talk more about decomposers, decomposed decompose dead organisms. You know as the body breaks down and then it gets decomposed by decomposers such as fungi, earthworm, snails and much more. Every organism has its own way of producing and taking sunlight for energy. As an example there is a plant known as a producer that is taking sunlight from the sun as energy, and then a rabbit comes and eats the plants known as a primary consumer who eats producers. Then a fox comes and eats this rabbit. A fox is a secondary consumer that's eats primary consumers and producers. Then a hawk comes and eats the fox a hawk is a tertiary consumer knowing that he ate a secondary consumer.

APPENDIX C

Sample of a Student's Transcribed Interview

Student 11's Transcribed Interview:

1. 'Forest ecosystems get their energy from the sun'

Researcher: You said in your writing 'Forest ecosystems get their energy from the sun.' Can you explain what you mean by that?

Student: Yes, Mrs. sun gives energy for the plants so they can grow. That's the energy. Photosynthesis. That's how they get their energy. Mrs. from the sun and water.

Researcher: Okay and what do you mean by 'their energy'?

Student: Mrs. cause they produce their own energy so it's 'their' energy.

Researcher: And how do they get energy from the sun?

Student: Mrs. by… Mrs. when the sun comes like at at them. Mrs. they get their energy.

Researcher: You said the word 'get' which means take something. Do you really think they are getting something from the sun?

Student: Mrs. yes. The energy. So they can produce energy, they need the sun.

Researcher: People say 'Getting credit is greater when it is deserved' do they really mean that they are getting something?

Student: Mrs. can you repeat your question?

Researcher: People say sometimes 'Getting credit is greater when it is deserved' do they really mean that they are getting something?

Student: Mrs. no. (silent) Mrs. yes of course if you get something yes.

Researcher: How is this way of speaking similar or different to when you refer to the 'Forest ecosystems get their energy from the sun'?

Student: Mrs. it's similar.

2. ‘Plants take that energy’

Researcher: You said ‘Plants take that energy’ can you explain what you mean by that?

Student: Mrs. yes. Eh plants take that energy from the sun so they can pass it on to other living living things.

Researcher: You said that ‘the plants take that energy’ Do the plants really ‘take’ something?

Student: No Mrs. they don’t like actually take it Mrs. but they need eh their like the sun sunlight so that they can produce energy.

Researcher: People say ‘The girl takes her eye color from her mom’ do they mean she took the color from her mom’s eye?

Student: No Mrs. DNA.

Researcher: How is this similar or different to ‘plant takes its energy from the sun’?

Student: Mrs. eh Mrs. cause it’s getting its energy from the sun and the sun its already has the energy so.

Researcher: How does it compare to ‘the girl takes her eye color from her mother’ How are they similar or different, those two sentences?

Student: Mrs. it’s different I think.

Researcher: Okay, why is it different?

Student: Mrs. because it’s not from the DNA of the sun.

3. ‘plants take that energy and the animal eating it will take 10% of the energy’

Researcher: Then you said ‘plants take that energy and the animal eating it will take 10% of the energy’ can you explain what you mean by that?

Student: Yes, yes Mrs. animals that eat each other or plants will not take all the energy will take only 10% of that.

Researcher: How does the animal ‘take’ 10% of the energy?

Student: Mrs. by eating it.

Researcher: What about the rest of the energy?

Student: Mrs. it stay in the root.

Researcher: You said ‘animals take 10% of the energy’ does the animal really only take 10% of something?

Student: No Mrs. like cause they ate the plant and the plant eh has that energy so they take energy from the plant. It’s already in them.

Researcher: People say ‘You take 50% of the responsibility for breaking this window’ do they really mean that someone took 50% of the responsibility’? They took 50% of

something.

Student: No Mrs.

Researcher: How is this saying similar or different from ‘animals take 10% of the energy’?

Student: Mrs. I think it’s similar because they take that 10% for themselves so they can actually survive.

4. ‘Then the other animal will eat the animal that has that energy’

Researcher: The you said ‘then the other animal will eat the animal that has that energy’ can you explain what you mean by that?

Student: Mrs. yes. The like the… the predator will eat that animal so it can get that energy from them.

Researcher: Where does the animal have this energy?

Student: Mrs. form the plant. And the plant gave that energy to the other animal and the other animal ate the other.

Researcher: You said ‘animal has energy’ and when someone ‘has’ something they will own it. Do you really think that the animal has and owns something?

Student: Mrs. I don’t… Mrs. yes of course.

Researcher: People say ‘He has good ideas’ do they really mean that he has something?

Student: Mrs. no… He has good ideas Mrs. he has he doesn’t انو own it.

Researcher: How is this saying similar or different from ‘animal has energy’?

Student: Mrs. ah they don’t own it Mrs. they get it. Mrs. so like when they eat it mrs. they get it. Like they don’t own it.

Researcher: And ‘he has good ideas’ how is it different?

Student: Mrs. he has good ideas Mrs. It’s… eh … Mrs. it’s similar because he got the ideas like it’s not he doesn’t own the ideas. It’s not something you can own.

Researcher: Would you like to add anything else?

Student: No

APPENDIX D

Sample of Coding of Segments of Students' Elaborations in Interviews Through a Process of Open-coding Using a Constant Comparative Method

Substance Contained

- the energy is like in the trees eh in the airborne creatures (S1)
- energy in the ground as in grass and decomposers. (S1)
- it (energy) is inside it's leaves (S1)
- the energy is in the fish (S1)
- it (energy) is carried inside the fish (S1)
- the animals move the energy with them like migrating birds move to different countries (S1)
- they have energy inside them (S1)
- From the sun (where is energy found) (S4)
- From each other (where is energy found) (S4)
- have the energy from its food. (S5)
- Yes eh from food their body break down energy stored in the in them. (S6)
- there is mechanical energy it's found يعني above in the upper part of the ocean (S7)
- when waves like eh eh like show up there's energy in them. (S7)
- Energy is not really moving بس it's found there in the ocean and while the ocean is moving it's found انو in a particular place (S7)
- a source of energy that he will eat should last him a long time(S8)
- a snake would have a bigger source than a mouse so yes I think energy can be stored in one of these sources. (S8)

- a snake will not find a mouse (source of energy) like far away from an oasis (S8)
- the energy in the organism (S9)
- energy is inside of them to help them work and stuff (S9)
- It needs; The plants trap the energy from the sunlight (S10)
- light energy the solar energy from the sun (S10)
- it (energy) stay in the root. (S11)
- from the sun and water (energy found in). (S11)
- you will have this energy in your body (S12)
- food is in their eh in the plants so the plants will have energy (S12)
- the energy that was in the plant this animal will have it (S12)
- From the sunlight (energy found) (13)
- the energy belongs to the animal and it's um his use. (S14)
- the energy that is left in the dead organisms, (S15)
- they won't have more energy (S15)
- plant has its own source to get energy (S15)
- he's also out of energy (S15)

Energy transferred

- They eat the plants and each other (answer to how the energy moves up the food chain) (S1)
- Consuming the leaves (answer to how is energy gained). (S1)
- pass it down (S2)
- sun basically gives them rays that gives them energy (S2)
- it (energy) eh eh transfer them to another place (S2)
- they can get energy is by eating something (S3)

- They ‘eat’ the plant (to get energy) (S3)
- By eating the plant (get energy) (S3)
- animals eat some animals eat the plant so they get energy from the plant. (S4)
- the hamster and the lizard and the ants are eating the grass and then the snake is eating the hamster that is getting from the grass energy. (S4)
- the hamster gives then the energy for the snake and the snake for the eagle and to the rest (S4)
- animals get their energy from food (S5)
- energy is gonna be um required to be carried from one another (S5)
- it’s like going from one to another (S5)
- if a dog is having no energy he’s going to eat to have energy and drink water. (S5)
- mouse and the mouse has just ate his food and he’s having his energy (S5)
- when they eat plants and animals. (S6)
- they have the energy and some organisms feed on them. So the energy eh transports from this like from the phytoplankton to the other organisms. (S7)
- It belonged to the microbes but when they ate it, it’s it’s just how life works they took the energy (S7)
- when the shark eats the fish it’s taking the energy from the fish to the shark. So yea I do think they’re taking something. (S7)
- the source (gives energyto predator) is the like living thing that this predator is eating. (S8)
- When you or the predator eat an organism or like its source of energy the energy is getting transferred (S8)

- the primary consumers ah will eat the plant and will get like 10% of the energy in the pant (S9)
- 10% will go to the primary consumer and its 10% will go only to the secondary consumer so it will travel throughout the food chain. (S9)
- Like when an organism when an organism sorry eats one another like the energy travels through them. (S9)
- rabbit needs to eat the carrot in order to get energy. (S9)
- animals that eat each other or plants will not take all the energy (S11)
- the predator will eat that animal so it can get that energy from them. (S11)
- sun gives energy for the plants so they can grow. (S11)
- plants take that energy from the sun so they can pass it on to other living living things. (S11)
- the plant gave that energy to the other animal (S11)
- when you eat and drink you will have the energy to move to do something (S12)
- energy is when you eat or drink something (S12)
- energy is eh delivered to our body by eating and drinking (S12)
- Like energy is eating and drinking so energy will be delivered (S12)
- When an animal comes and eats this plant he will also like energy will be delivered also to his body (S12)
- the sun is the one giving eh… the producers the energy (S14)
- I think it’s gone in the air or soil (S14)
- soil usually the usually gives energy also to the flowers other than the sun of course. (S14)
- (Energy is passed) When the animals eat the producer. (S14)

- rabbit eats a plant, مثلا he eats like a mushroom or something and then he he some of the energy passed on to the rabbit (S15)
- the energy gets passed on to the fox (S15)
- most of the energy gets eh goes back into nature. (S15)
- the rest of the energy and they put it back into life so again a plant will grow back (S15)
- animals who eat the plants and animals who eat animals and plants to eh to get their energy (15)
- Animals their way eh is taking energy from plants في eh other animals their way is taking energy from uh other animals (S15)
- the rabbit eating the plant to get eh to get its energy the fox now, the fox is the ah secondary consumer, so they eat plants and animals. (S15)
- foxes also won’t have anything to ah to eat or like you know anything to get to get energy from. (S15)
- consumers they have their own source of taking energy which is like eating the plants (S15)

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